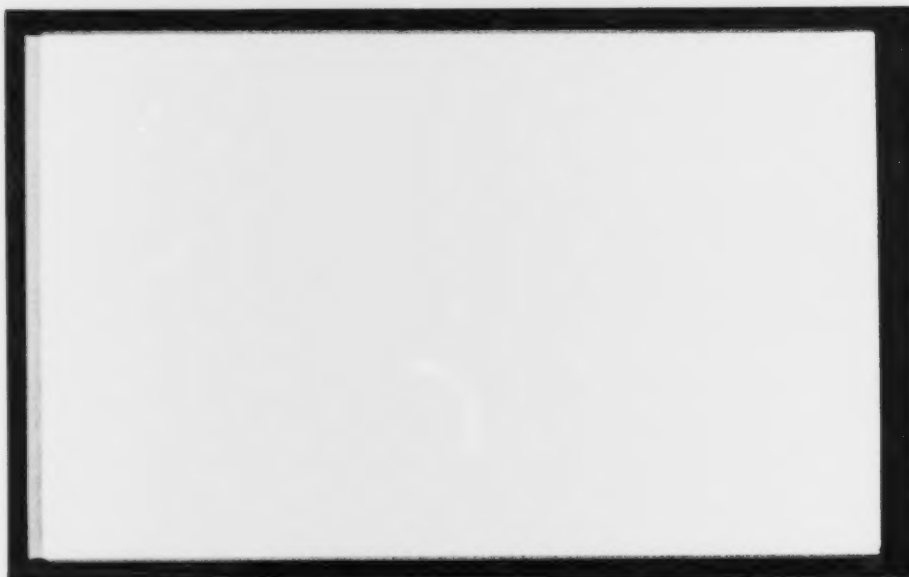


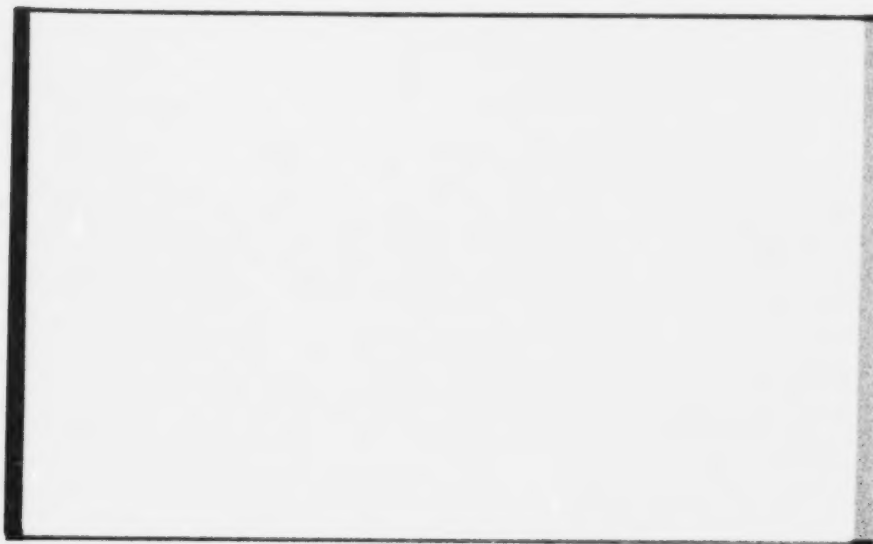


Saskatchewan
Energy and Mines

HEAVY OIL PROJECT



Although the Department of Energy and Mines has exercised all reasonable care in the compilation, interpretation, and production of this publication, it is not possible to ensure total accuracy, and all persons who rely on the information contained herein do so at their own risk. The Department of Energy and Mines and the Government of Saskatchewan do not accept liability for any errors, omissions, or inaccuracies that may be included in, or derived from, this publication.



THE IMPACT OF HEAVY OIL DEVELOPMENT ON
HIGHWAYS AND MUNICIPAL ROADS IN SASKATCHEWAN

Prepared For:
SASKATCHEWAN ENERGY AND MINES
SASKATCHEWAN HIGHWAYS AND TRANSPORTATION
SASKATCHEWAN RURAL DEVELOPMENT

Prepared by:
SPARKS & ASSOCIATES LTD.
Saskatoon, Saskatchewan

JANUARY, 1986

Sparks & Associates Ltd.

Professional Consulting Engineers & Planners

2220 Avenue C North, Saskatoon, Saskatchewan S7L 6C3 • Telephone (306) 653-4511

January 30th, 1986

Ms. Peggy Clark
Heavy Oil Consultant
Saskatchewan Energy and Mines
1914 Hamilton Street
Regina, Saskatchewan
S4P 4V4

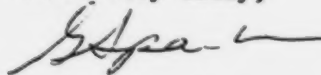
Dear Ms. Clark,

We take pleasure in submitting this report entitled "The Impact of Heavy Oil Development on Highways and Municipal Roads". We wish to express our sincere appreciation for the assistance which you, other members of the Steering Committee, your respective staff members, as well as the numerous officials from Rural Municipalities and oil companies extended to us during the course of this project.

We hope that the information presented in this report will be of assistance to you in the deliberations related to heavy oil development within Saskatchewan.

Thanking you,

Yours very truly,



Gordon A. Sparks

GAS/gs

EXECUTIVE SUMMARY

The overall objective of this project was to assess the impact of heavy oil development on regional highways and municipal roads within 6 RM's in the west central area of Saskatchewan.

During the course of the project, it was determined that:

- 1) The traffic volumes observed on many of the municipal roads within the RM's with intense heavy oil development were in the range of 100 - 200 vehicles per day, with some roads carrying 300 - 500 vehicles per day. Approximately 50% of this traffic was oil related and consisted of a high proportion of truck traffic. These volumes compare with peak volumes of 100 - 200 vehicles per day on similar roads in RM's without oil development. These volumes of 300 - 500 vehicles per day exceed the volumes observed on some surfaced Provincial highways.
- 2) The costs of maintaining gravel municipal roads are primarily associated with the costs of blading, regravelling and reconstruction. Within the study area, many roads required blading approximately every 10 days, and regravelling annually.

Typical blading and regravelling costs were in the range of \$800-1200/km/year. Roads rebuilt in the 1960's are found to require reconstruction after only 20 years service. This reconstruction is required in part to re-establish the cross-section and profile of the roadway and in part, in response to a need to upgrade the roadways to a higher standard so as to provide an acceptable level of service to higher volumes of traffic.

Reconstruction costs range from \$15,000 - 55,000/km.

- 3) In RM's with intense heavy oil development, traffic counts indicated that approximately 50% of all traffic at some locations was oil related and RM oil related revenues amounted to 80% or more of total transportation related expenditures. RM officials identified an on-going need to upgrade substantial numbers of roadways within these RM's to meet the higher demands. RM's were found to be unable to up-grade roads in a timely manner because of inadequate availability of funds for road reconstruction.
- 4) In RM's where heavy oil development was in its initial stages of development, traffic counts indicated that approximately 50% of the total traffic was oil related and oil related revenues

From the above, consideration should be given to:

- 1) Establishing a program whereby RM's are in a position to reconstruct roadways in a timely manner to standards which will provide an acceptable level of service relative to demand.
- 2) Establish a program to ensure that in RM's where oil related revenue lags oil generated costs, that the RM is capable of providing and maintaining roadway infrastructure. A special case exists where RM's incur the costs of providing roads, yet do not and/or will not receive oil related revenue because of a lack of such development within the boundaries of the R.M.
- 3) Establishing a program whereby the RM is capable of implementing a dust control program. As a minimum, this dust control program should address the problem on high volume roadways near farmsteads and high volume intersections.

The above programs would most appropriately be developed and funded on the basis of case by case need.

amounted to only 20-30% of total transportation related expenditures. This tends to substantiate the contention put forward by RM officials that revenues from oil tend to lag oil related traffic demands and the need to provide and maintain roadways.

- 5) Some RM's were found to be incurring the costs of providing and maintaining roads to meet oil related demands but had little or no oil related revenues to offset these costs.
- 6) Dust on high volume roadways was found to be a nuisance and a potential safety hazard. Dust was a nuisance particularly on high volume roads near farmsteads and a safety hazard at high volume intersections. The use of waste oil and sand as a dust suppressant is not typically very cost/ effective. This type of surface tends to break-up under traffic and requires an expensive re-work to repair. The use of thin pavements or oiled surfaces to provide a dust free surface can be a very expensive alternative. Experience indicates that it can cost \$3,000-10,000/km/year to maintain such surfaces. Heavy duty pavements on the other hand have lower maintenance costs but cost \$200,000 - 300,000 per km to construct.

TABLE OF CONTENTS

Chapter One: Introduction	1
1.1 Background	1
1.2 Study Objectives	3
1.3 Study Scope	4
1.3.1 Study Area	4
1.3.2 Study Time Frame	4
1.3.3 Data and Analysis Requirements	6
1.3.4 Other Considerations	7
1.4 The Report Layout	9
 Chapter Two: Traffic	 11
2.1 Introduction	11
2.2 Growth in Traffic	33
2.3 Composition of Traffic	33
2.4 Oil Related Activities	41
2.5 Future Traffic	62
2.6 Summary	67
 Chapter Three: Road Costs	 69
3.1 Introduction	69
3.2 Performance of Roads	69
3.2.1 Loading	75
3.2.2 Soil Conditions	79
3.2.3 Typical Field Conditions	84
3.2.4 Observed Phenomena	89
3.2.5 Oil Treatment and Heavy Duty Pavements	93
3.3 Costs of Maintaining Roads	100
3.3.1 Blading Costs	101
3.3.2 Gravelling Costs	104
3.3.3 Total Costs	106
3.3.4 Summary of Costs	109
3.3.5 Alberta Policy	115
3.3.6 Other Considerations	116
3.4 Summary	119
 Chapter Four: Expenditures and Revenue	 122
4.1 Introduction	122
4.2 RM Transportation Expenditures	122
4.3 RM Oil Related Revenues	125
4.4 Provincial Oil Royalties	128
4.5 Future Oil Related Revenues	128
4.6 Comparison of Revenues and Expenditures	131

Chapter Five: Summary

140

List of References

145

**Appendix A: Total RM Transportation Expenditures
RM's with Heavy Oil Developments**

LIST OF FIGURES

Figure 1.1	Study Area	5
Figure 2.1	Traffic Flow Map RM No. 352	12
Figure 2.2	Traffic Flow Map RM No. 469	13
Figure 2.3	Traffic Flow Map RM No. 471	14
Figure 2.4	Traffic Flow Map RM No. 472	15
Figure 2.5	Traffic Flow Map RM No. 501	16
Figure 2.6	Traffic Flow Map RM No. 502	17
Figure 2.7	Traffic Flow Map RM No. 36	18
Figure 2.8	Traffic Flow Map RM No. 66	19
Figure 2.9	Traffic Flow Map RM No. 139	20
Figure 2.10	Traffic Flow Map RM No. 168	21
Figure 2.11	Traffic Flow Map RM No. 320	22
Figure 2.12	Traffic Flow Map RM No. 321	23
Figure 2.13	Traffic Flow Map RM No. 73	24
Figure 2.14	Traffic Flow Map RM No. 245	25
Figure 2.15	Traffic Flow Map RM No. 246	26
Figure 2.16	Traffic Flow Map RM No. 340	27
Figure 2.17	Traffic Flow Map RM No. 402	28
Figure 2.18	Traffic Flow Map RM No. 436	29
Figure 2.19	Location of RM's Within Saskatchewan	30
Figure 2.20	Total Travel in RM vs RM Type	32
Figure 2.21	Vehicle Classification Counts RM No. 352	35
Figure 2.22	Vehicle Classification Counts RM No. 469	36
Figure 2.23	Vehicle Classification Counts RM No. 471	37
Figure 2.24	Vehicle Classification Counts RM No. 472	38
Figure 2.25	Vehicle Classification Counts RM No. 501	39
Figure 2.26	Vehicle Classification Counts RM No. 502	40
Figure 2.27	Composition of Traffic	43
Figure 2.28	Monthly Crude Production - Area 1 Lloydminster	46
Figure 2.29	Location of Producing Wells RM No. 352	48
Figure 2.30	Location of Producing Wells RM No. 469	49
Figure 2.31	Location of Producing Wells RM No. 471	50
Figure 2.32	Location of Producing Wells RM No. 472	51
Figure 2.33	Location of Producing Wells RM No. 501	52
Figure 2.34	Location of Producing Wells RM No. 502	53
Figure 3.1	Road Performance Model for Gravel Roads	71
Figure 3.2	Distribution of Stress Created in Subgrade Soil as a Function of Tire Pressure	77
Figure 3.3	Intensity of Stress in Soil on Centre-Line Below Tire for Constant Pressure q for Increasing Wheel Load	78
Figure 3.4	Mechanisms of Displacement of Softened Soil Caused by Stress in Subgrade (Created by Tire Pressure) Exceeding "Strength" of Soil	80
Figure 3.5	Strength of Glacial Till	81
Figure 3.6	Strength of Glacial Till	82
Figure 3.7	Strength of Glacial Till Before and After 4 Freeze-Thaw Cycles	85
Figure 3.8	Reduction in "Strength" of Soil Caused by Increasing Number of Load Applications	86

Figure 3.9	Distribution of Moisture in Gravel or Oil Surface Road During Dry Summer Weather	88
Figure 3.10	Distribution of Density in Percent of Standard Density	88
Figure 3.11	Photographs Illustrating Field Conditions	96-100
Figure 3.12	Blading Frequency and Traffic Flow Map	102
Figure 3.13	Blading Frequency vs Traffic Volume, RM No. 472, 1985	103
Figure 3.14	5 Year Gravel Required vs Traffic Volume, RM No. 472, 1981-1985	105
Figure 3.15	Annual Cost for Blading and Gravelling vs Traffic	108
Figure 3.16	Comparison of Costing Models	110
Figure 3.17	Transportation Services Expenditures vs Total Travel in RM	112
Figure 4.1	RM Transportation Services Expenditures vs RM Type	124
Figure 4.2	Oil Revenues and Oil Related Transportation Expenditures	132
Figure 4.3	Light Oil RM Revenues and Expenditures, 1984	133
Figure 4.4	Traffic - Expenditures - Revenues, RM No. 472, 1984	137

LIST OF TABLES

Table 2.1	Estimated Total Travel	34
Table 2.2	Composition of Traffic	42
Table 2.3	Producing Wells by RM	47
Table 2.4	Estimated Oil Related Vehicle Kilometres	56
Table 2.5	Estimated Total Oil and Non-Oil Related Travel	57
Table 2.6	Monthly Produced Fluid Arrivals at Typical Cleaning Plants	61
Table 2.7	Enhanced Oil Recovery Projects in Saskatchewan	63
Table 2.8	Saskatchewan Heavy Oil Area Drilling Projections 1985 - 1990	64
Table 3.1	Average Cost of Gravel, \$/Yd ³	107
Table 3.2	Typical Highway Cross-Sections and Average Costs	114
Table 4.1	Total Transportation Expenditures	123
Table 4.2	Summary of RM Revenues, RM's in Heavy Oil Area	126
Table 4.3	Summary of RM Revenues, RM's With Light/Medium Oil Developments	127
Table 4.4	Provincial Royalties from Crude Oil Production in Area 1	129
Table 4.5	Provincial Land Sale Revenues from Area 1	130
Table 4.6	Summary: Traffic - Revenues - Expenditures - Wells	134

Chapter One: Introduction

1.1 Background [1] [2]

Heavy oil development within the west central area of Saskatchewan is the long term future of oil development in Saskatchewan. This development presents the Province with some unique opportunities. It however also presents some significant challenges. One such challenge relates to the provision of road infrastructure to meet the demands of heavy oil development in addition to existing traffic demands.

Oil development generates certain transportation requirements. Initial drilling and completion activity and servicing of the wells results in substantial traffic on regional highways and municipal roads as drilling rigs move to well sites, supplies are provided during drilling, and the wells are serviced while in production. These transportation needs are common to all oil development, however due to the nature of heavy oil, the servicing requirements for heavy oil well sites is somewhat greater than for light to medium oil wells.

Also, in the longer term, the impact on the highway and road system in the heavy oil areas of the province relates to the oil collection process. Light and medium oils are generally pipelined, however, in its raw state, which is an emulsion consisting of oil, gas, water and sand, heavy crude cannot be

pipelined for more than a half mile because line pressure drops become excessive beyond this radius. To be transported by pipeline for greater distances, heavy oil must first be put through a "battery" where the sand, gas and water are separated. This separated heavy oil has such a high viscosity that in order to be pipelined long distances, it must be blended with a condensate which acts as a dilutant on the viscous oil, allowing easier pipelining and less horsepower for further distances.

A battery can handle the crude produced by many wells. The wells within a half mile of the battery can be serviced with a pipeline. However, product from wells further than a half mile from the battery must be trucked from the well to the battery. It is this traffic that may have a long term impact on the road system. A substantial portion of the heavy oil traffic will be generated on regional highways and municipal roads. In a few instances, a municipality may have the additional expenses associated with this traffic, but no revenue because there are no wells located within its boundaries.

Given the anticipated increase in demand for the provision and maintenance of roadway infrastructure, there is a need to quantify this increased demand and to assess its incremental impact upon area roads so that the demands can be met in an equitable, efficient and cost effective manner by those responsible for the various components of the road system.

With this in mind, Saskatchewan Energy and Mines in co-operation with Saskatchewan Highways and Transportation and Saskatchewan Rural Development, in May 1985, invited interested consultants to submit a proposal detailing their approach to the required study. The firm of Sparks & Associates Ltd. was subsequently commissioned to undertake the study and this report documents the findings.

1.2 Study Objectives

The overall objective of the project was to assess the impact of heavy oil development on regional highways and municipal roads. In addition to the overall impact of heavy oil development, the incremental impact relative to existing base traffic and that which would be associated with light to medium oil development areas was also to be quantified and assessed. This incremental impact is important in terms of determining an equitable distribution of responsibility for the provision of road infrastructure to meet the increased demands.

1.3 Study Scope

1.3.1 Study Area

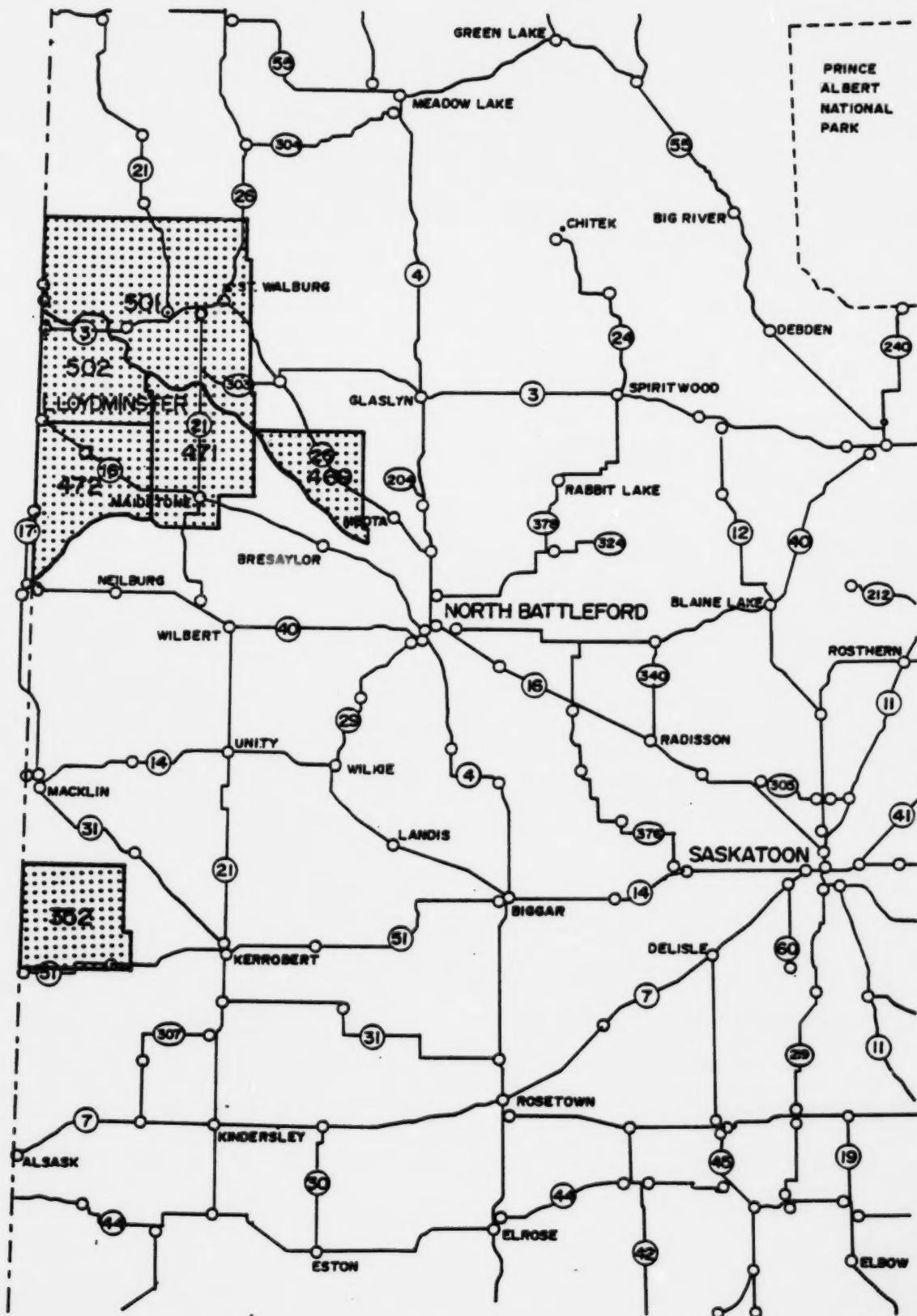
The area of heavy oil reserves in Saskatchewan extends westward from Range 15 west of the 3rd Meridian to the Alberta-Saskatchewan border, and from Township 32 northwards to Township 55. Development to date has been predominantly centered in the six municipalities within this larger area, illustrated in Figure 1.1, including the RM's of Heart's Hill No. 352, Turtle River No. 469, Eldon No. 471, Wilton No. 472, Frenchman Butte No. 501, and Brittania No. 502. Continued development is expected in these established areas with new discoveries taking place in the undeveloped areas.

While the methodology developed in this study to assess the impact of heavy oil development upon the road infrastructure was to be universally applicable, the focus of this effort was to be directed to assessing the impact within the six municipalities identified above.

1.3.2 Study Time Frame

The study was to be limited to two five year periods, the past five years (1980 - 1984) and the next five years (1985 - 1989).

FIGURE 1.1
STUDY AREA LOCATION



1.3.3 Data and Analysis Requirements

The existing heavy oil related traffic within the study area was to be identified, quantified and assigned by type to the existing highway and municipal road network. This total traffic was to include where possible, a breakdown by drilling and completion, servicing and oil collection activities.

In order to be able to assess the incremental impact of heavy oil development relative to light/medium oil development, traffic associated with drilling and completion, servicing and oil collection in a typical light/medium oil development was to be estimated and compared with that for the heavy oil development areas.

Estimates of future traffic for 1985 - 1989 were to be developed for the heavy oil developments in the six identified RM's.

Estimates of the incremental capital and maintenance costs, if any, by highway or road type attributable to heavy oil traffic were to be developed. These incremental costs by road segment were to be allocated to the jurisdiction responsible for each road segment for each of the past five years (1980 - 1984) and for each of the next five years (1985 - 1989).

A determination of the revenue which accrues to both the Province and to individual Municipalities from the heavy oil industry was to be made. This determination was to include tax and royalty revenue, oil related assessments and revenues, fees from permits and licence applications, and any other direct revenues. In addition, all conditional and unconditional grants received by the Municipalities for road construction and maintenance were to be identified and quantified as are all existing funds paid by the oil industry to Municipalities within the study area for road construction and maintenance not otherwise accounted for in the above.

An assessment of the adequacy of the existing roads to meet the demands of existing and future local and heavy oil related traffic was to be undertaken. Standards for roads which would be adequate to accommodate existing and future traffic were to be detailed.

The existing Alberta policy and practice as it relates to road and highway infrastructure impact in heavy oil development areas was to be reviewed and assessed respecting the applicability to the Saskatchewan situation.

1.3.4. Other Considerations

The success of this project will be determined by the degree of acceptance of the study by the various groups with vested interests. It was therefore critical that the study be

undertaken and presented in a comprehensive yet easily comprehended manner. It was important that all available data be assembled, reviewed, validated, augmented where necessary, and then be presented in an easily understood format so as to facilitate review and discussion by interested parties.

All analysis methods had to be clearly documented with all assumptions explicitly stated so that the logic of resulting conclusions and recommendations could be scrutinized and reviewed. More particularly, the primary purpose of the study was to provide the necessary data and technical background needed by those from various organizations involved in policy formations. The role of the project team was not to formulate policy, but rather to provide information to those charges with this responsibility.

In short, it was not enough to come forward with a number of conclusions and recommendations following the analysis of available data. This project, in order to be successful, had to result in conclusions which logically emerged from the data and analysis presented, and to which all interested parties could relate and reach a consensus.

1.4 The Report Layout

Chapter Two presents an overview of the traffic in terms of total amount by type for the rural municipalities (RM's) with heavy oil development, as well as RM's with light/medium oil and only agriculture. The oil related traffic was categorized by drilling, start-up, servicing, and oil collection activities. Estimates of future traffic were also developed.

Chapter Three summarizes the costs associated with providing and maintaining the roads in RM's with heavy oil, light/medium oil and only agricultural activities. This chapter also includes a discussion related to the performance of roads under traffic and develops estimates of typical levels of expenditures required to construct and maintain gravel, thin pavement and heavy duty paved roads. Comments related to dust control and road standards are also included.

Chapter Four presents a summary of the revenues received by both the Provincial and Municipal governments from oil related activities. This includes tax and royalty revenues, oil related assessments, fees and permits, conditional and unconditional grants and other direct revenues. Oil related traffic is compared with oil related revenues and total expenditures on transportation services by the RM's in the heavy oil area.

Chapter Five presents a series of summary comments.

Chapter Two: Traffic

2.1 Introduction

Figures 2.1 through 2.6 illustrate the total traffic in each of the six RM's with heavy oil under study herein. Figures 2.7 through 2.12 and Figures 2.13 through 2.18 respectively illustrate the total traffic in six RM's with light/medium oil developments and six with agriculture only. Figure 2.19 illustrates the location of these RM's within the province.

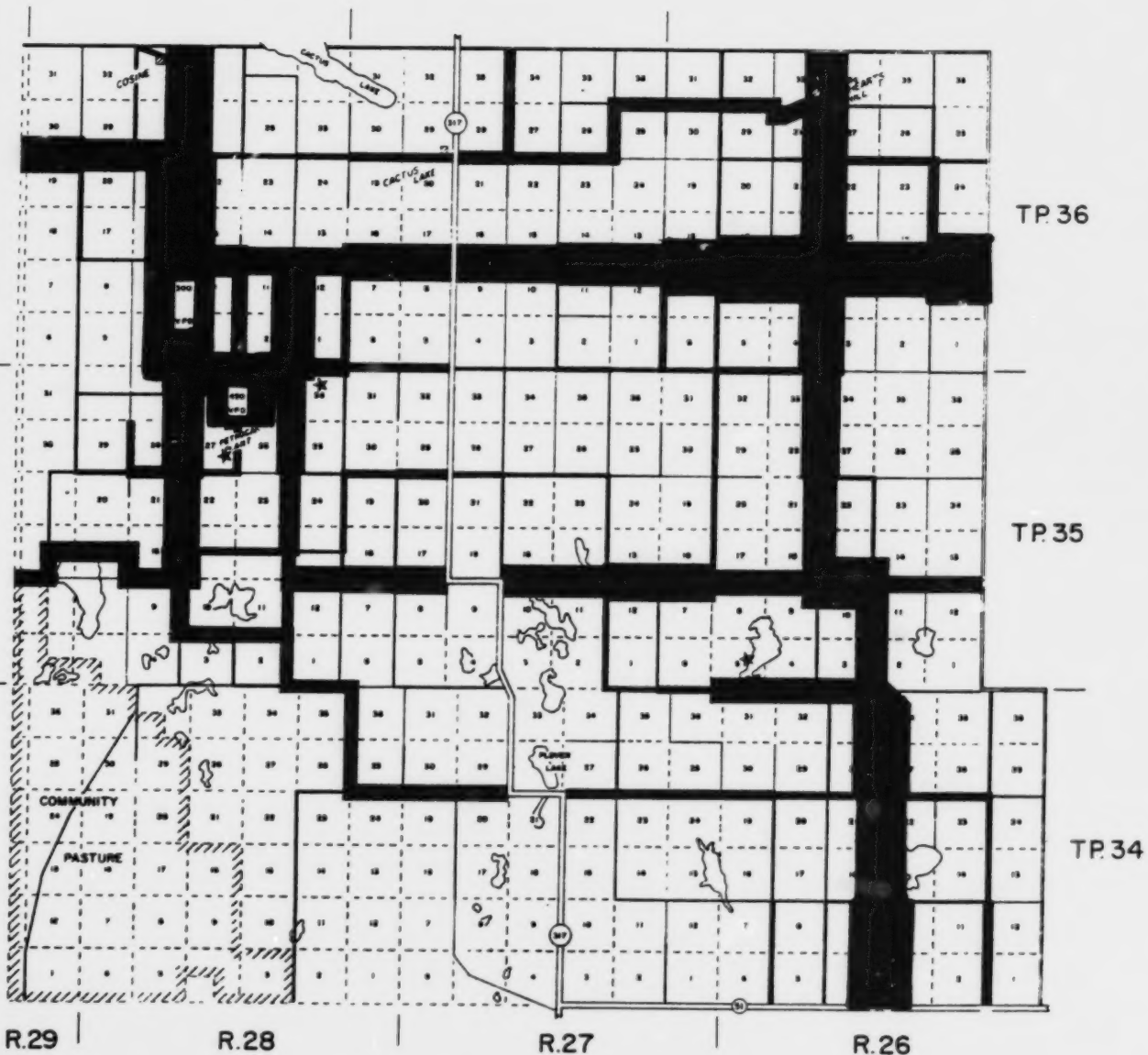
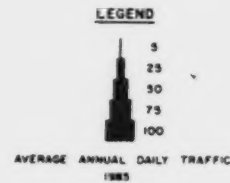
It is noted that the average annual daily traffic (AADT) on many of the municipal roads in the RM's with heavy oil are in the 100 - 200 vehicles per day range with some in the 200 - 400 range, and on some of the heavily travelled roads, volumes exceed 500 vehicles per day. These heaviest volumes compare and in many cases exceed the volumes on many Provincial Highways and therefore are in relative terms significant volumes of traffic, particularly when consideration is given to the fact that most are gravel surfaced roads.

Traffic volumes on the roads in RM's with light/medium oil development tend to be in the 100 - 200 vehicles per day range with some as high as 200 - 300 vehicles per day.

Traffic volumes on roads in RM's which are agricultural based are in the order of 50 - 100 vehicles per day, with a few

FIGURE - 2.1
TRAFFIC FLOW MAP

R. M. OF HEART'S HILL NO.352
(HEAVY OIL)
W. OF 3RD



T PREPARED BY TERRACON CONSULTING LTD
CONSULTING ENGINEERS

★ OIL BATTERY

JUNE 17-21, 1985

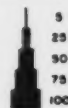
FIGURE-2.2

TRAFFIC FLOW MAP

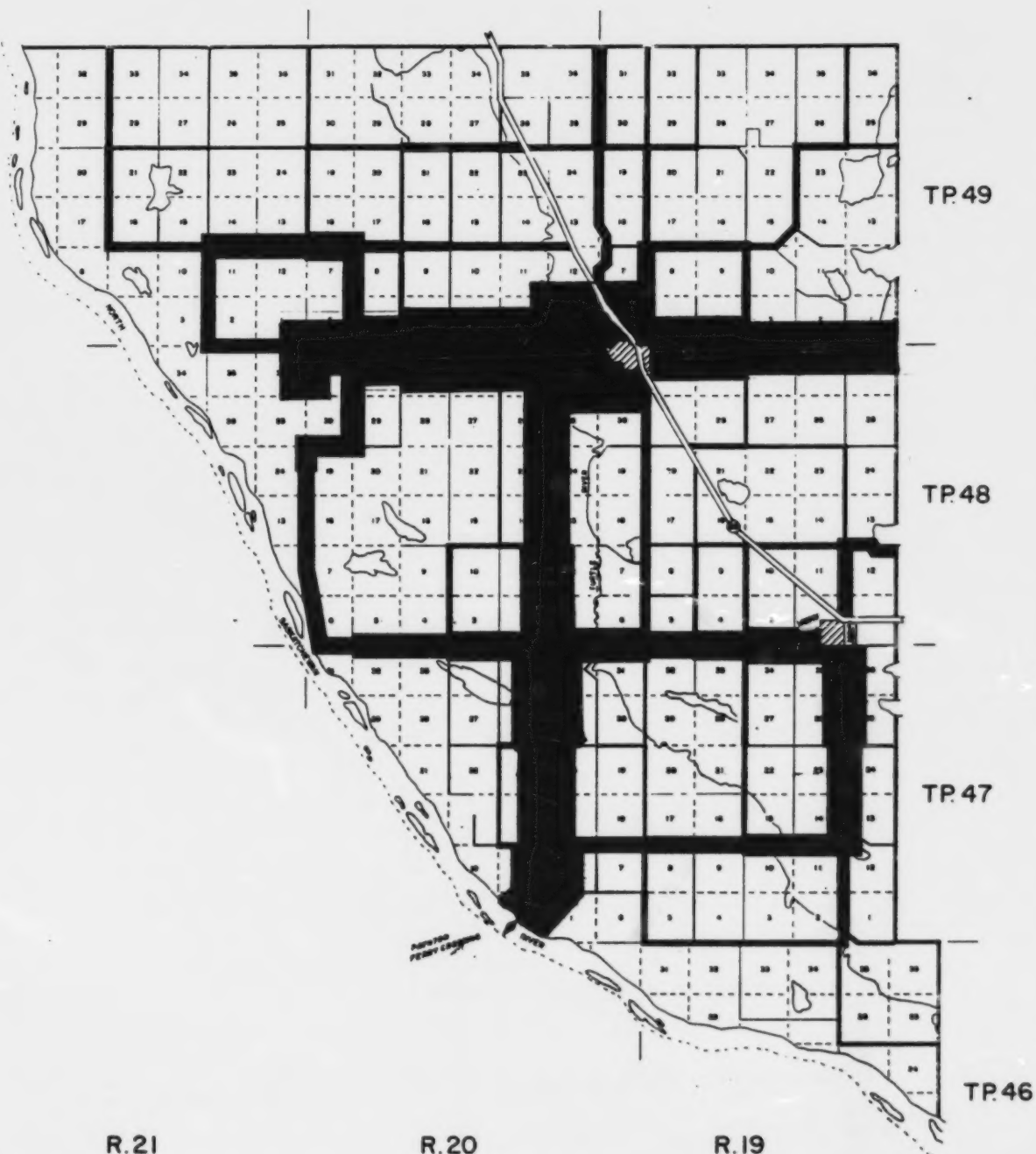
R.M. OF TURTLE RIVER NO.469
(HEAVY OIL)

W. OF 3RD

LEGEND



AVERAGE ANNUAL DAILY TRAFFIC
1985



DESIGNED BY: TRANSPORTATION CONSULTING LTD.

DATE: 10-10-85, REV 10-10-85

FIGURE 2.3
TRAFFIC FLOW MAP

R.M. OF ELDON NO. 471
(HEAVY OIL)
W. OF 3RD

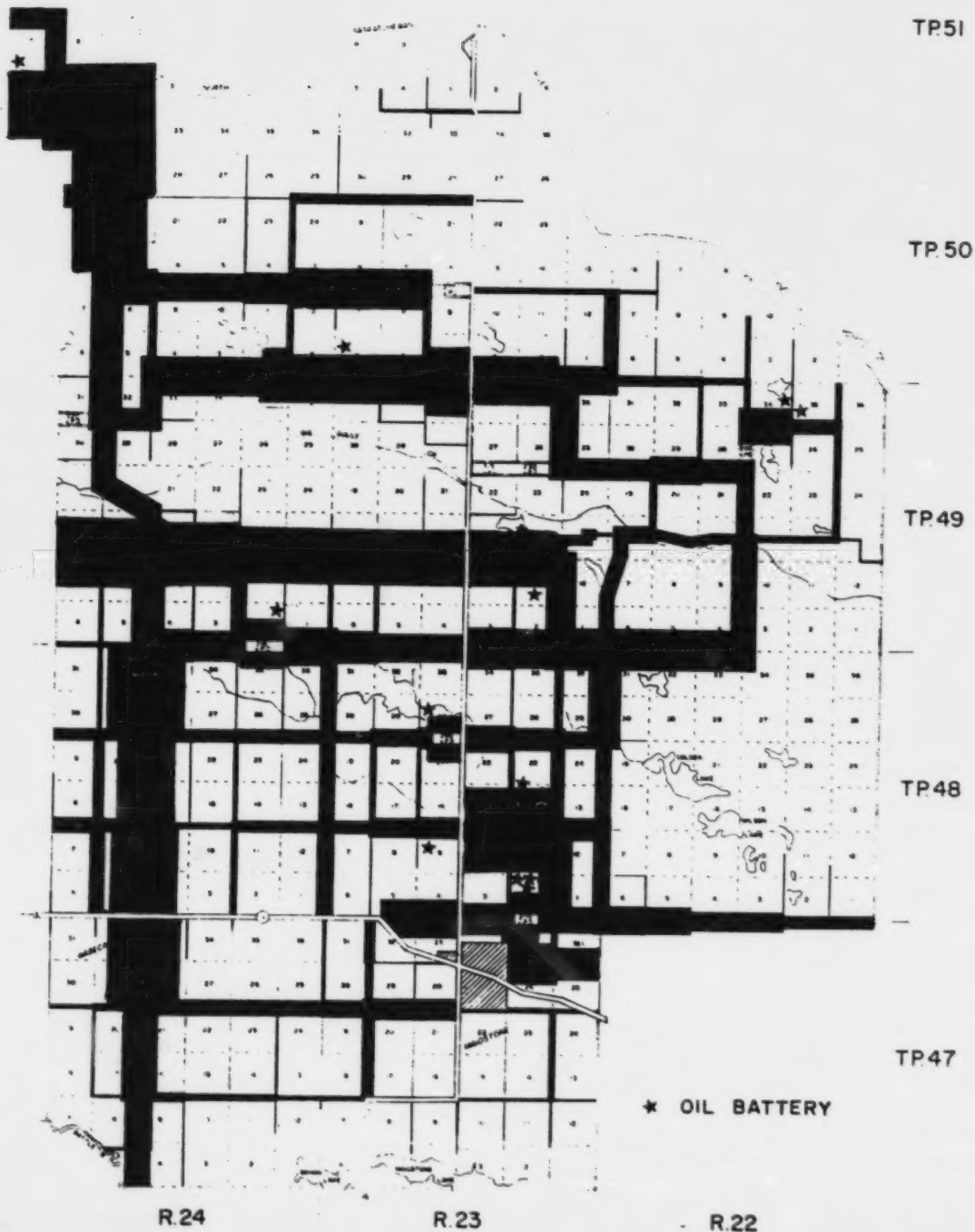
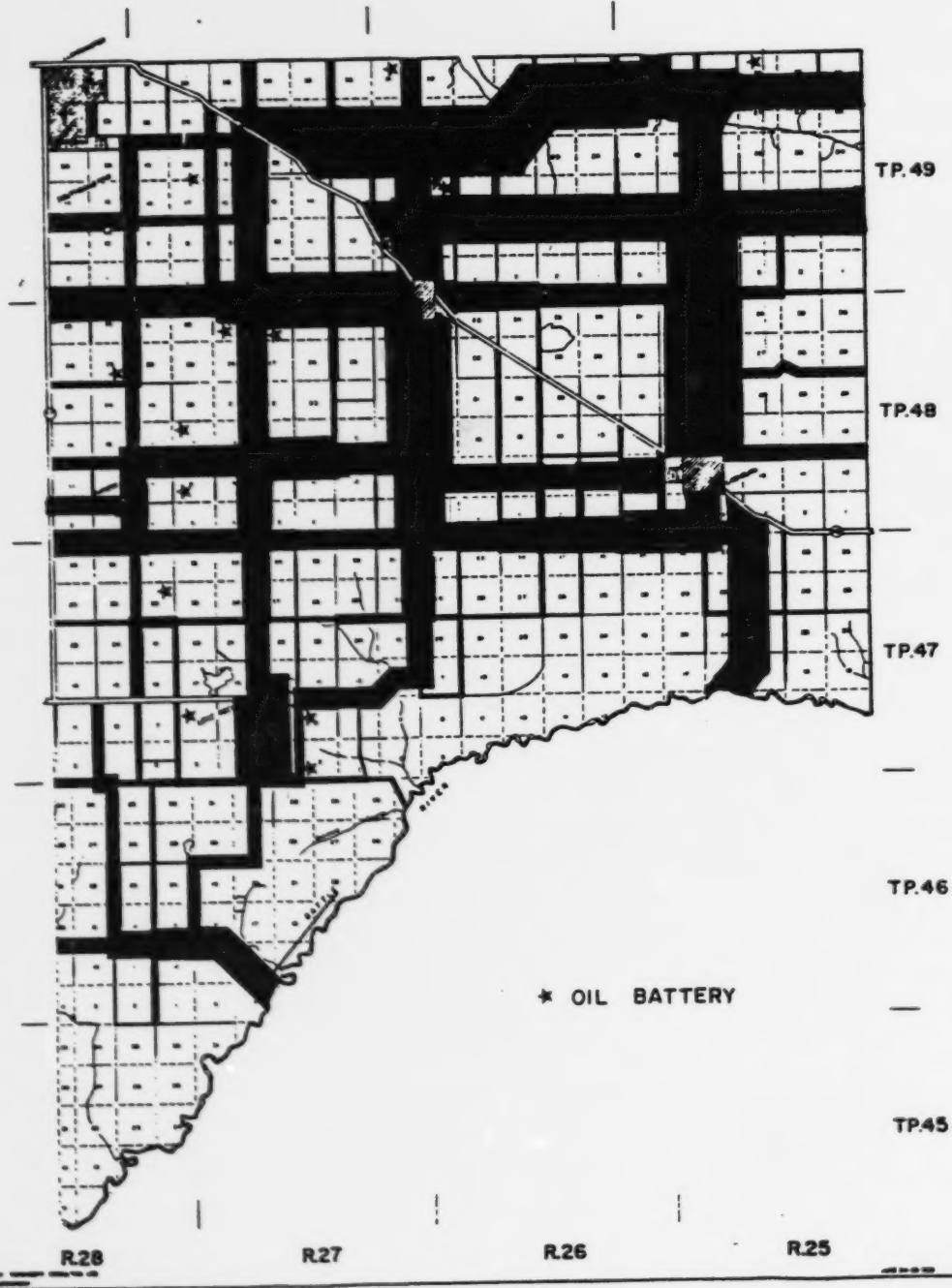


FIGURE - 2.4

TRAFFIC FLOW MAP

R.M. OF WILTON NO. 472
(HEAVY, OIL)
W OF 3RD



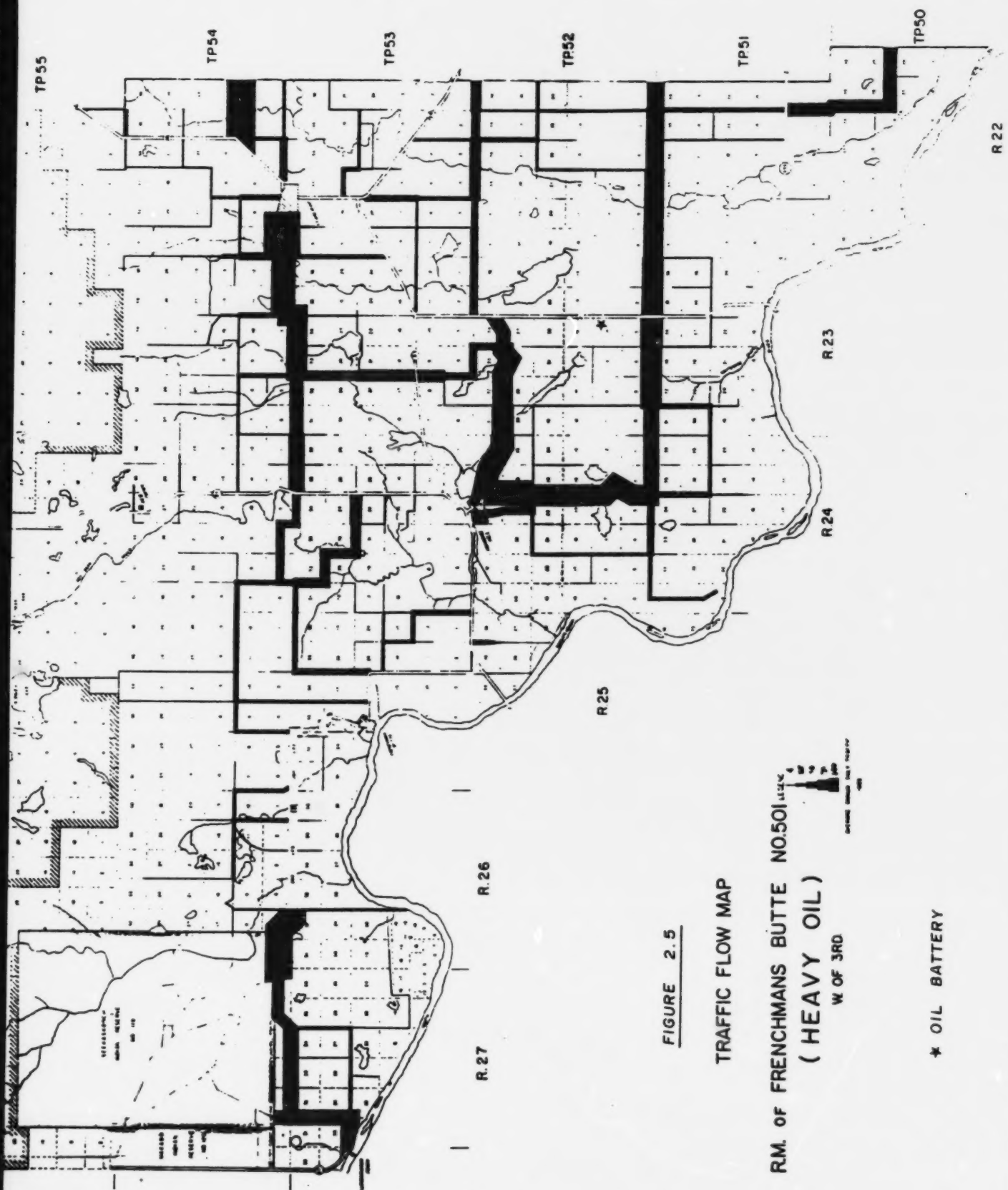


FIGURE 2.5

TRAFFIC FLOW MAP

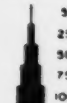
RM. OF FRENCHMANS BUTTE NO. 501
(HEAVY OIL)
W OF 3RD

FIGURE - 2.7
TRAFFIC FLOW MAP

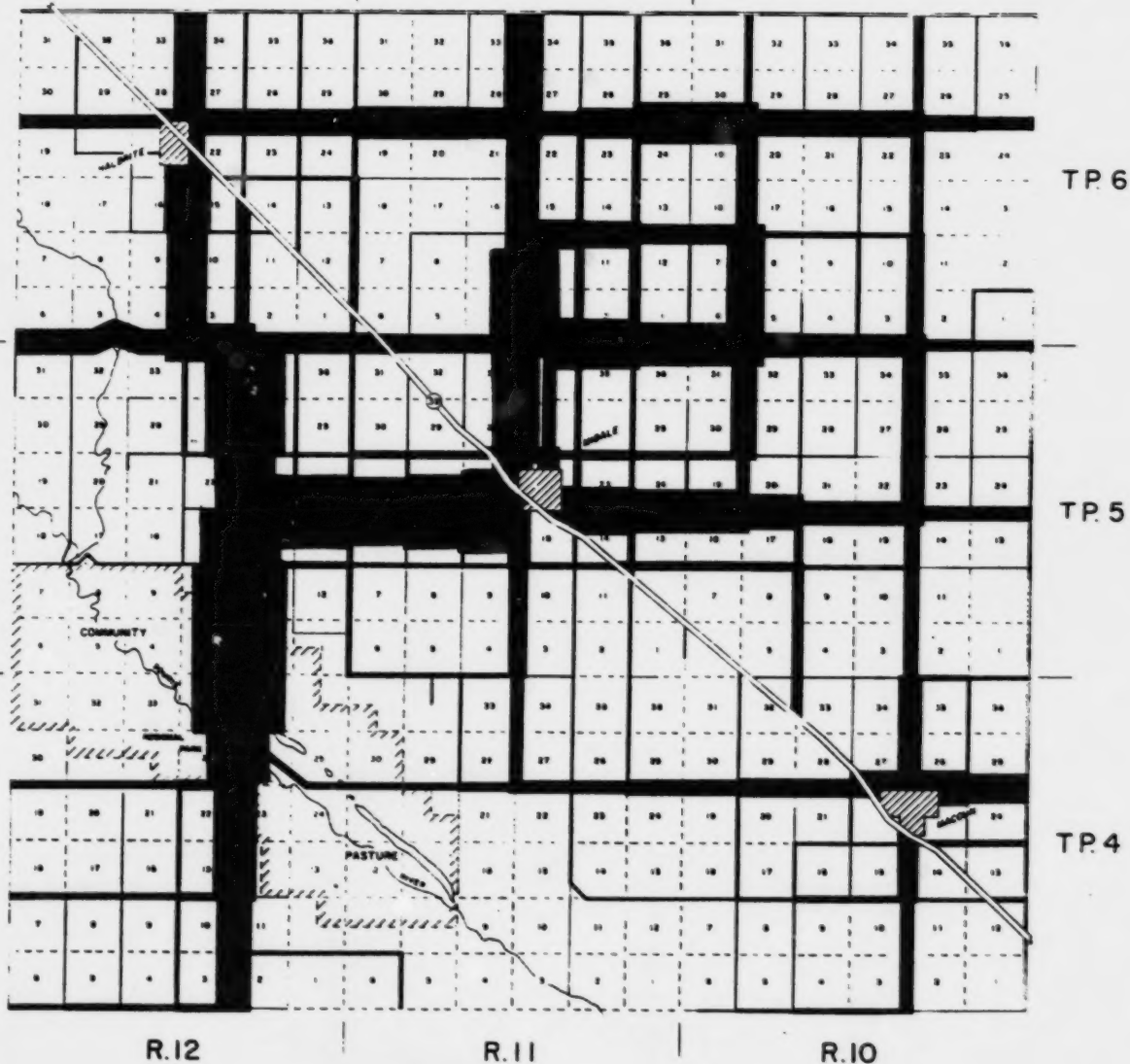
R. M. OF CYMRI NO.36
(LIGHT/MED. OIL)

W. OF 2ND

LEGEND



AVERAGE ANNUAL DAILY TRAFFIC
[1982]



PREPARED BY FORDHAM CONSULTING LTD.
CONSULTING ENGINEERS

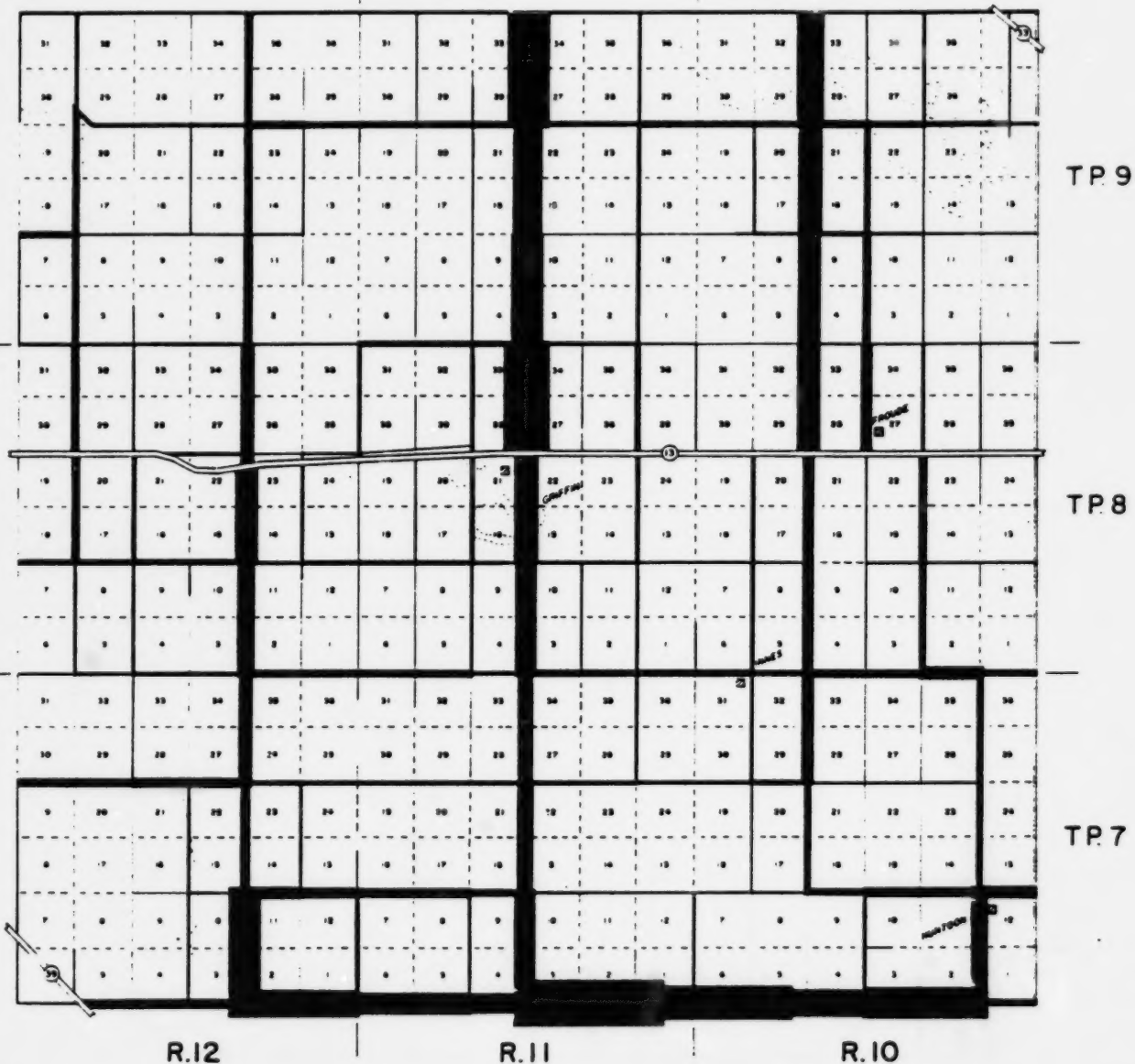
PLAN 11-1-102

FIGURE - 2.8
TRAFFIC FLOW MAP

R.M. OF GRIFFIN NO. 66
(LIGHT / MED. OIL)

W. OF 2ND

LEGEND



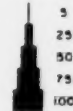
PREPARED BY: FORCHUCK & COMPANY LTD
CONSULTING ENGINEERS

AUG 9, 1962

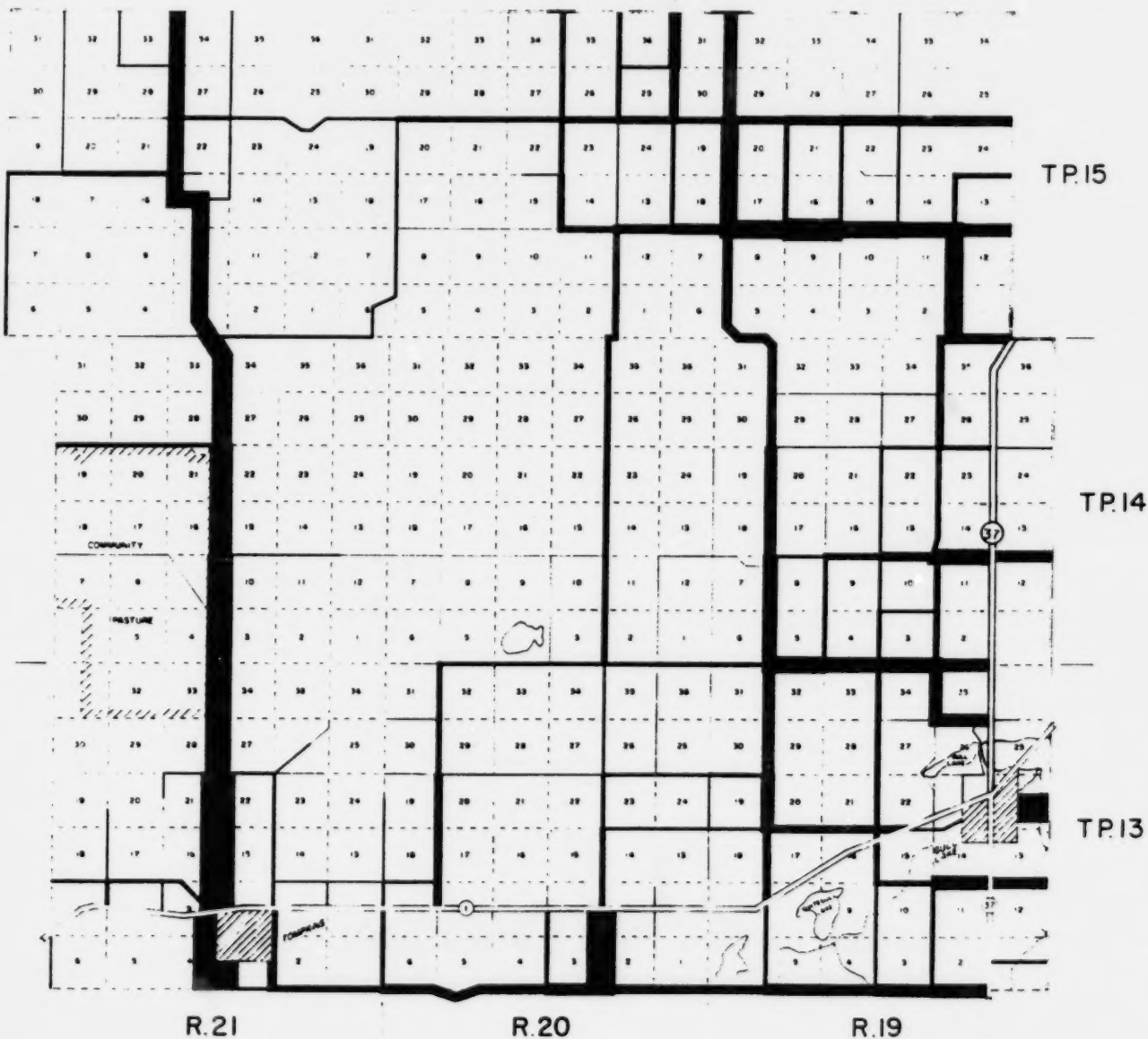
FIGURE-2.9
TRAFFIC FLOW MAP

R.M. OF GULL LAKE NO.139
(LIGHT / MED. OIL)
W. OF 3RD

LEGEND



AVERAGE ANNUAL DAILY TRAFFIC
392



R.21

R.20

R.19

FIGURE 2.10

TRAFFIC FLOW MAP

R.M. OF RIVERSIDE NO.168
(LIGHT / MED OIL)

W. OF 3RD.

TP.22

TP.21

TP.20

TP.19

TP.18

TP.17

TP.16

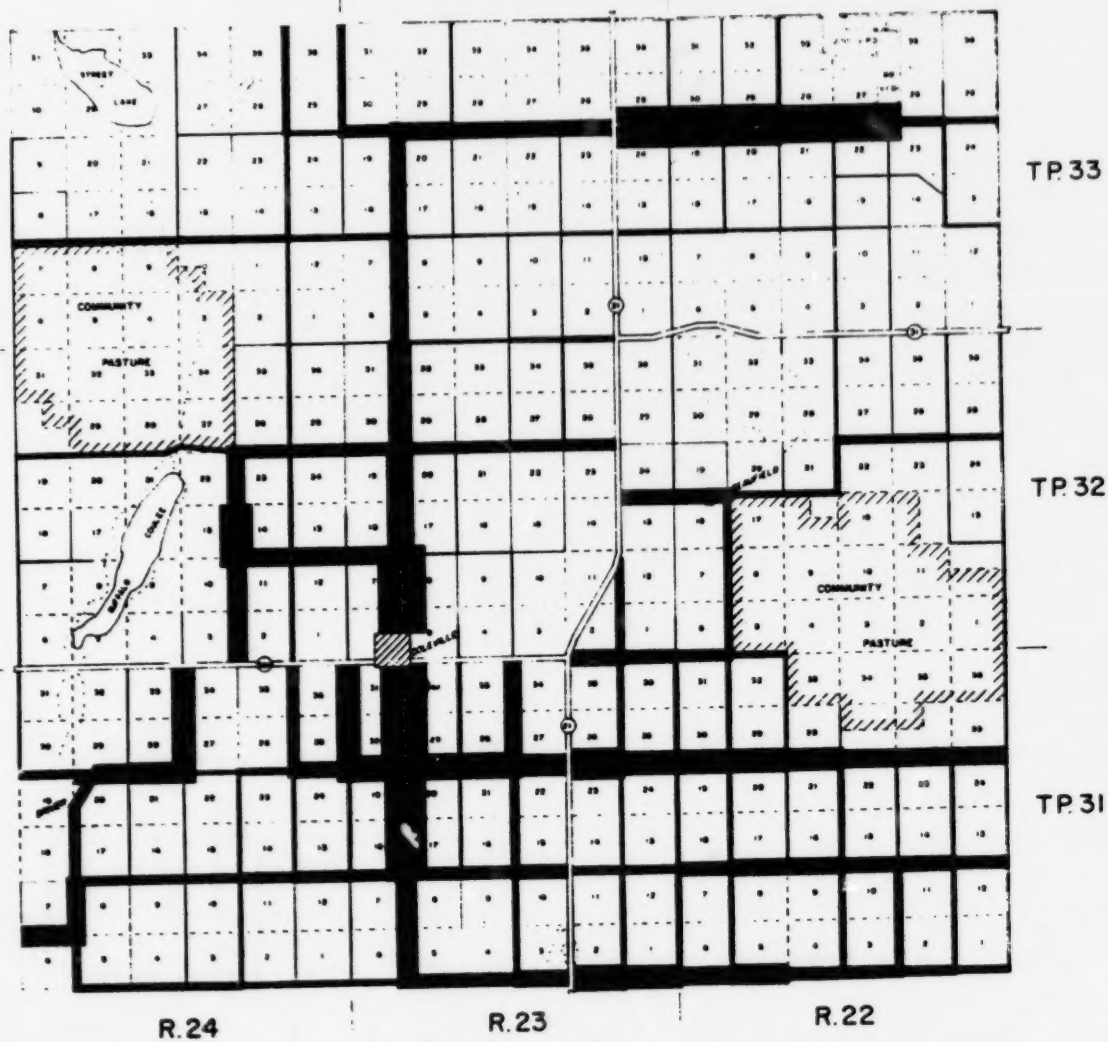
R.18

R.17

R.16

FIGURE - 2.11
TRAFFIC FLOW MAP

R. M. OF OAKDALE NO. 320
(LIGHT/MED OIL)
W. OF 3RD



T PREPARED BY: TARRANT COUNTY ENGINEERING LTD
COLUMBIA, TEXAS 76801

DATE: 11-15-80

FIGURE - 2.12

TRAFFIC FLOW MAP

R.M. OF PRAIRIEDALE NO.321
(LIGHT / MED OIL)
W. OF 3RD.

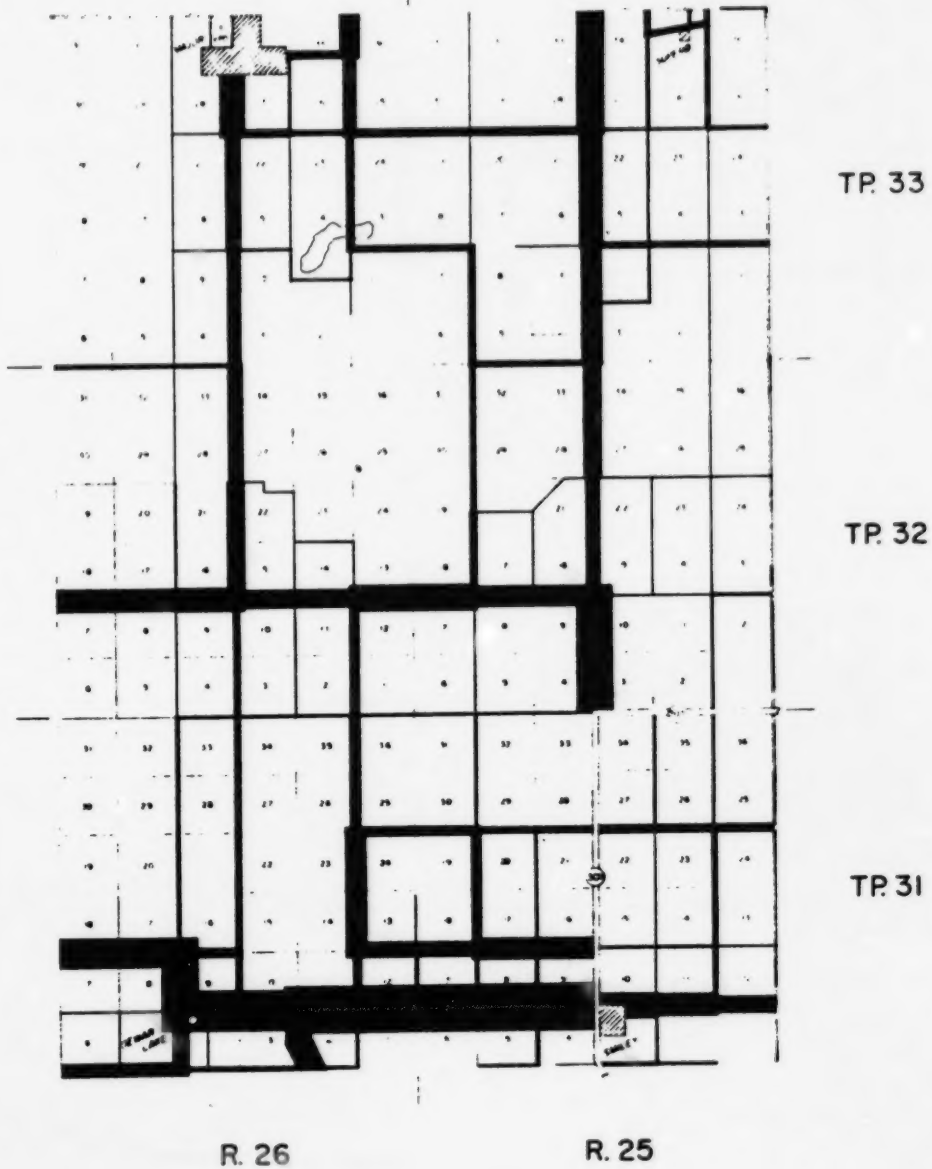
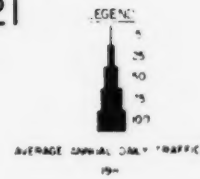


FIGURE - 2.13
TRAFFIC FLOW MAP

R.M. OF STONEHENGE NO.73
(AGRICULTURAL)
W. OF 2ND

LEGEND

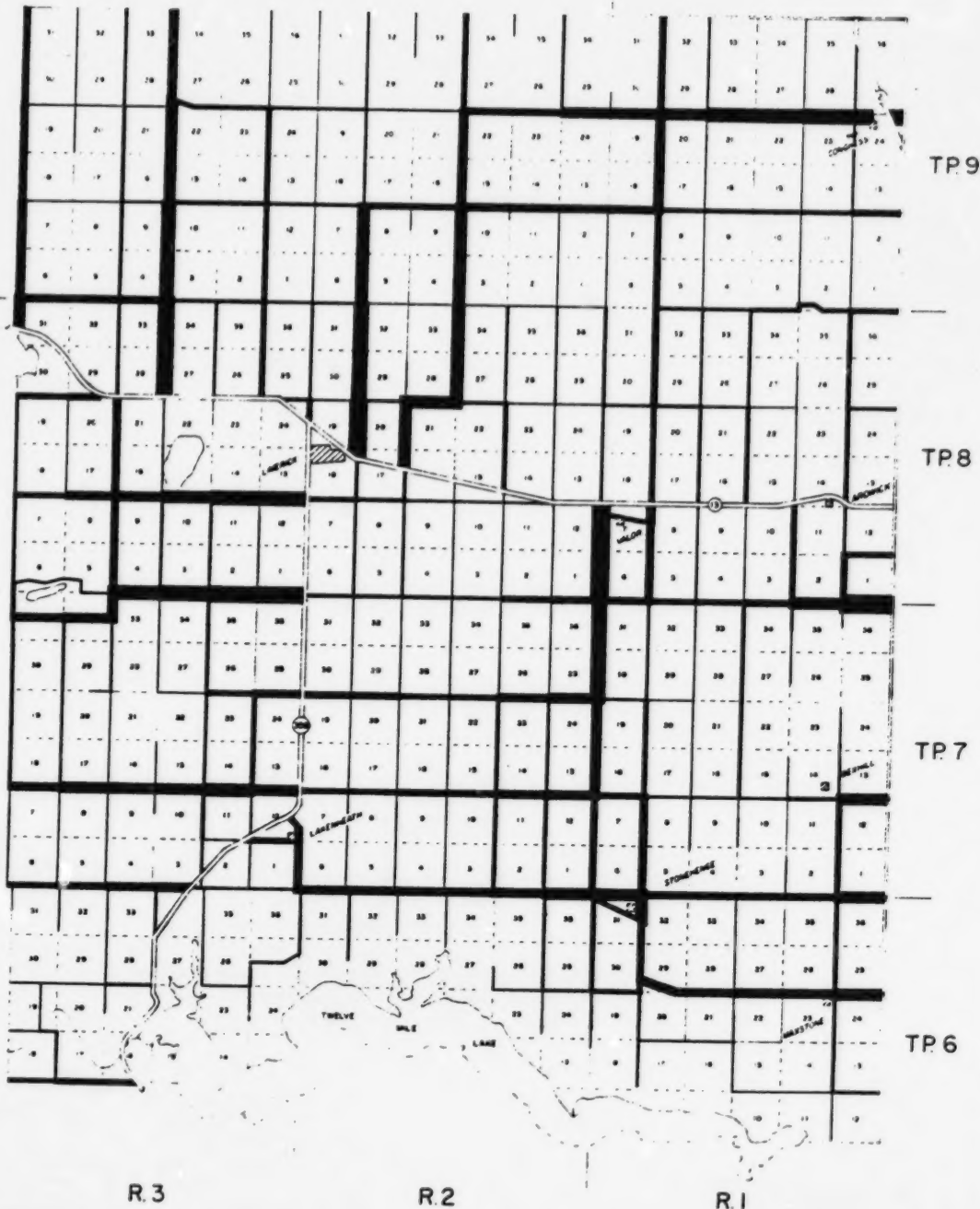


FIGURE -2.14

TRAFFIC FLOW MAP

RM. OF GARRY NO.245
(AGRICULTURAL)
W. OF 2ND.

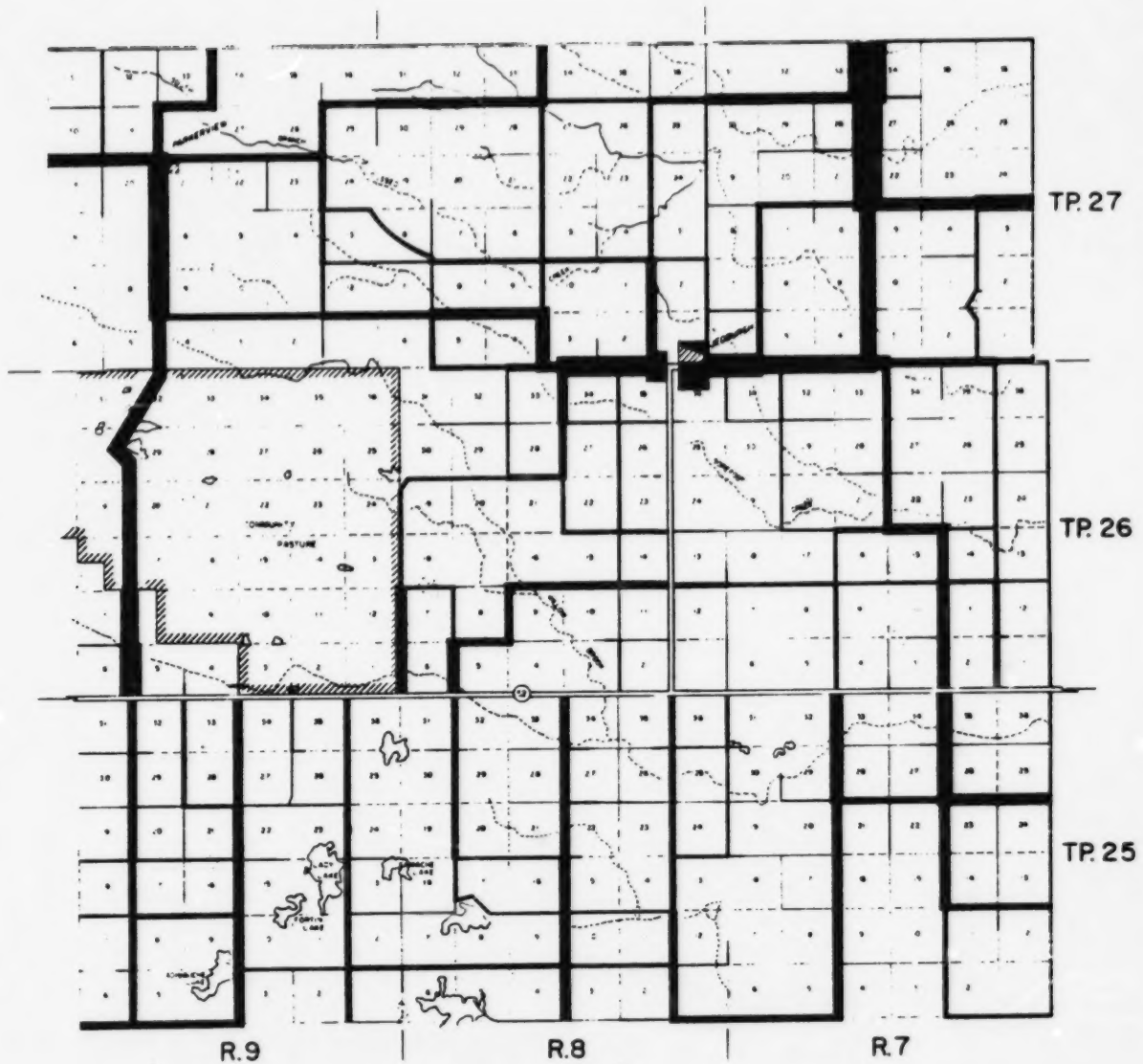
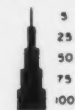


FIGURE - 2.15
TRAFFIC FLOW MAP

R. M. OF ITUNA BON ACCORD NO.246
(AGRICULTURAL)
W. OF 2ND

LEGEND



AVERAGE ANNUAL DAILY TRAFFIC
1982

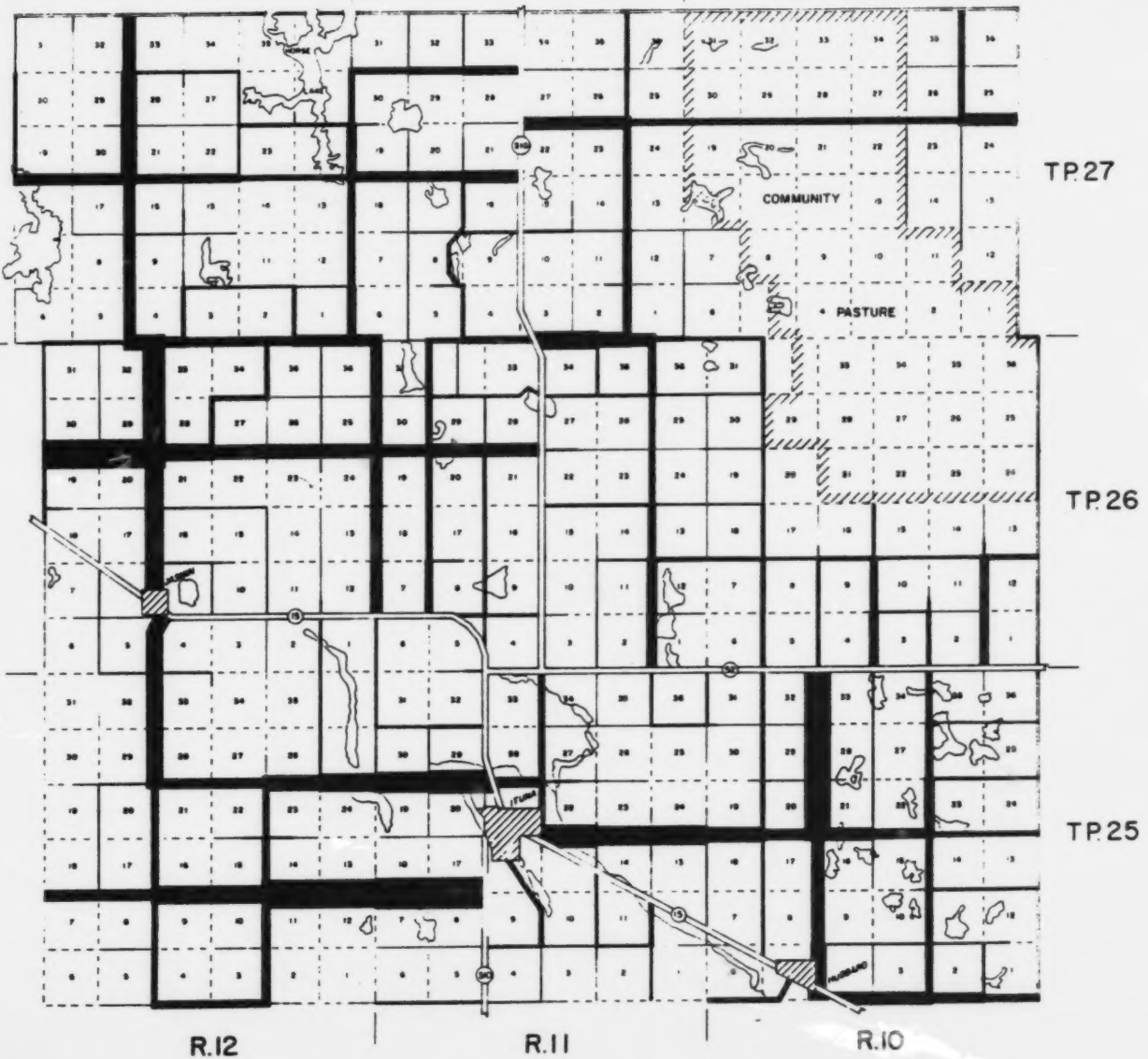


FIGURE-2.16

TRAFFIC FLOW MAP

R.M. OF WOLVERINE NO. 340
(AGRICULTURAL)

W. OF 2ND

LEGEND



AVERAGE ANNUAL DAILY TRAFFIC
1984

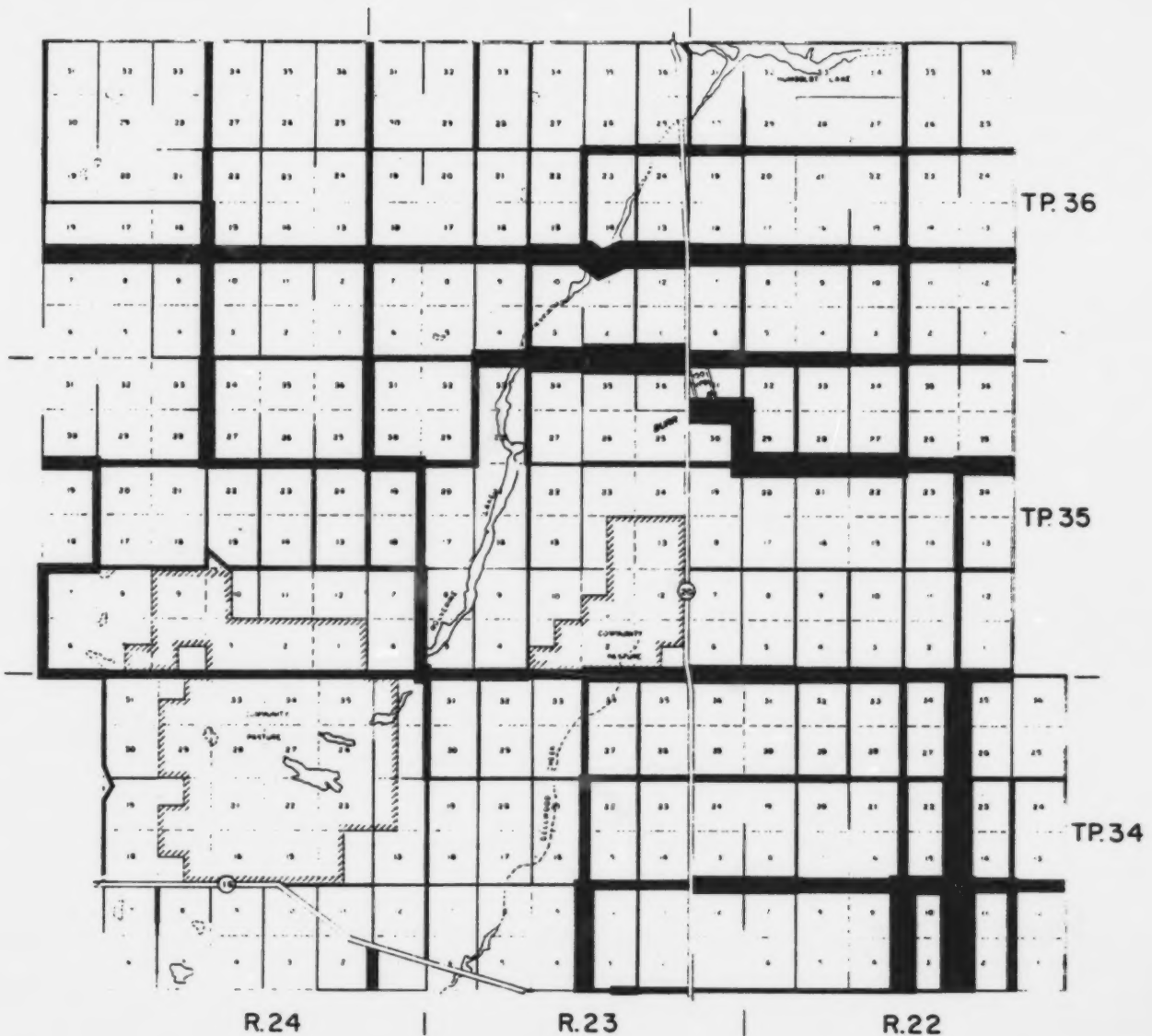
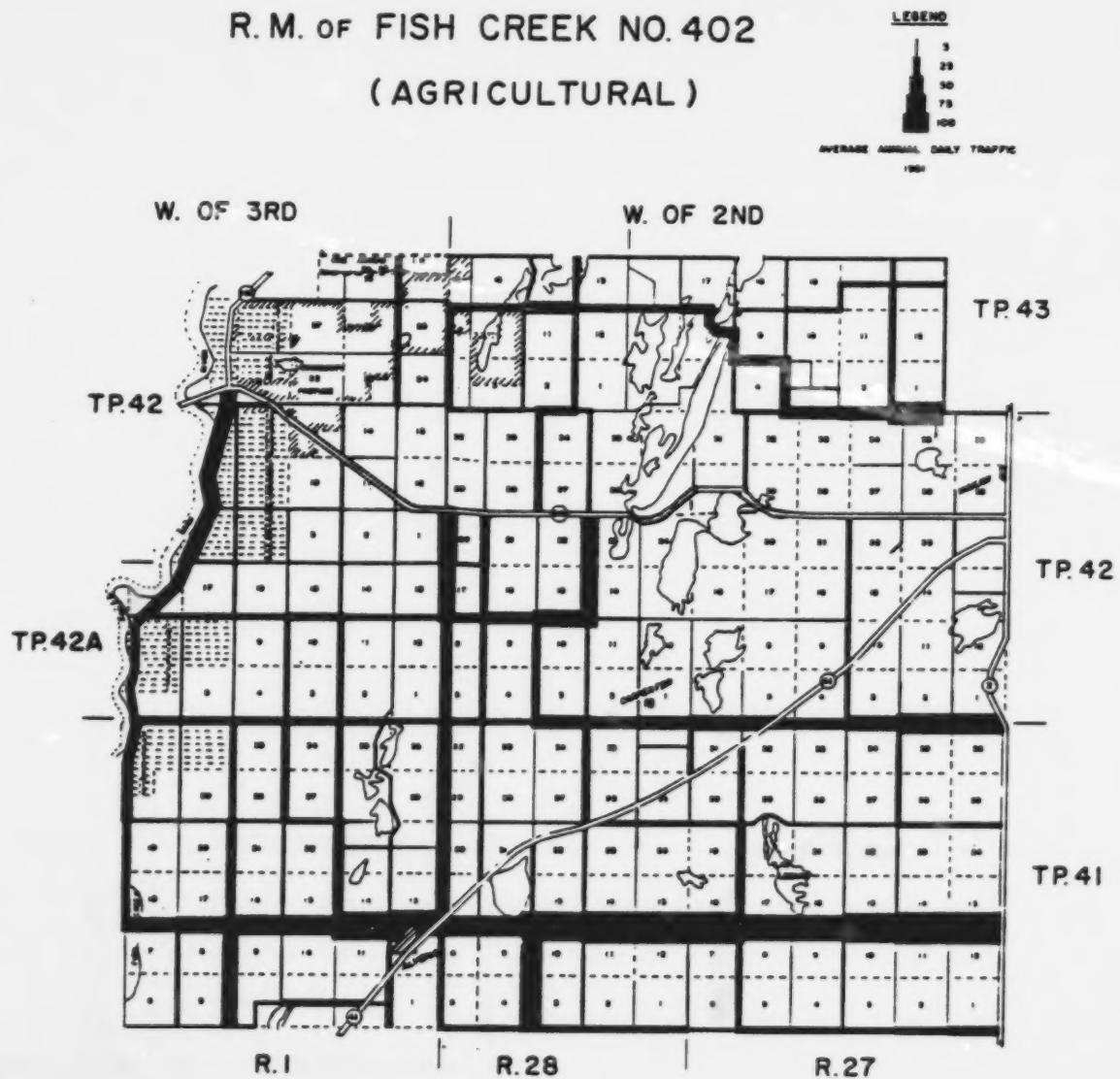


FIGURE 2.17
TRAFFIC FLOW MAP

R. M. OF FISH CREEK NO. 402
(AGRICULTURAL)



T PREPARED BY: FORESTRY CONSULTING LTD.
OPERATING ENGINEER

REV. 22-12-1961

FIGURE - 2.18
TRAFFIC FLOW MAP

R. M. OF DOUGLAS NO. 436
(AGRICULTURAL)

W. OF 3RD

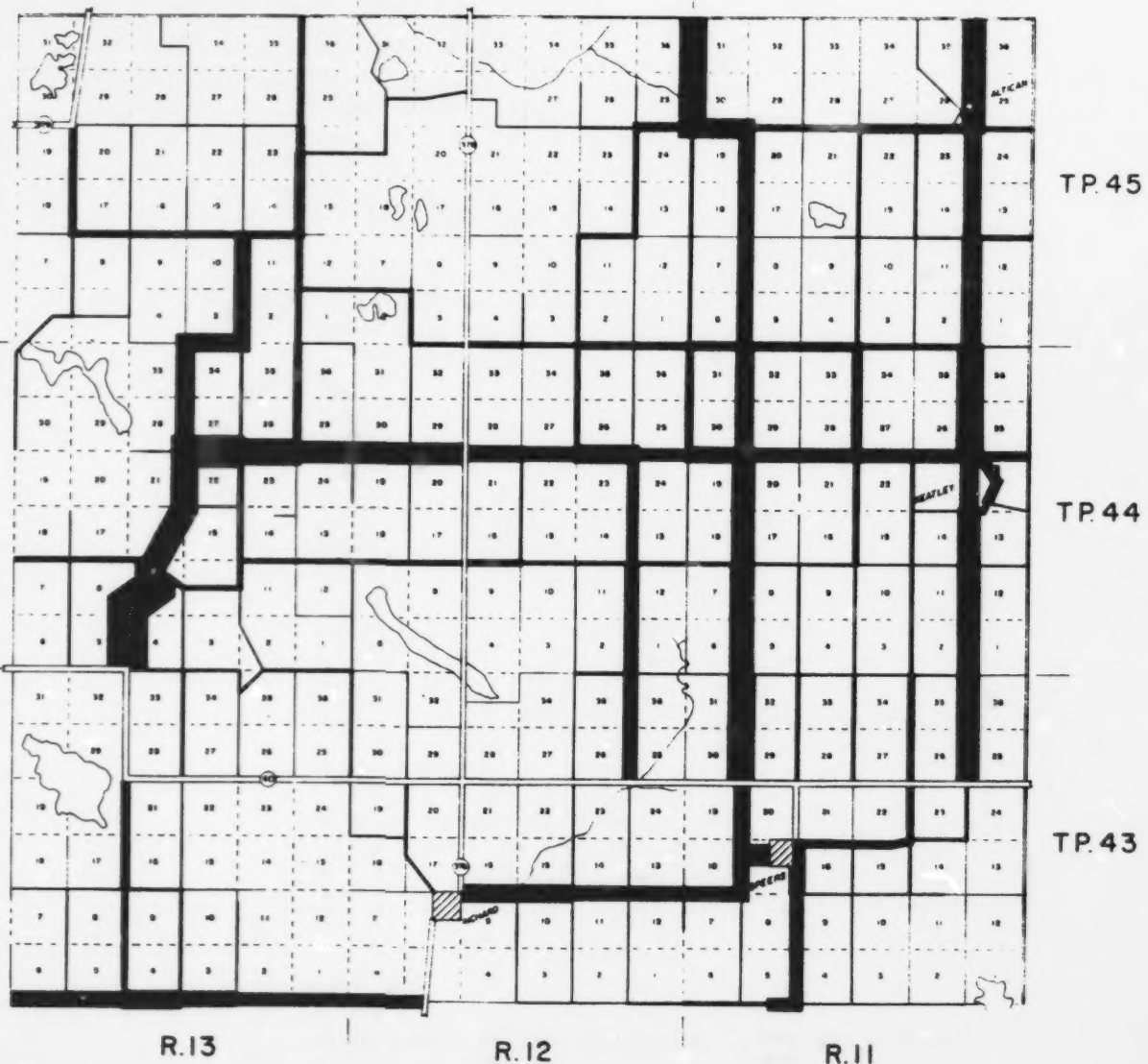
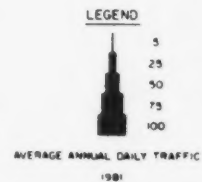
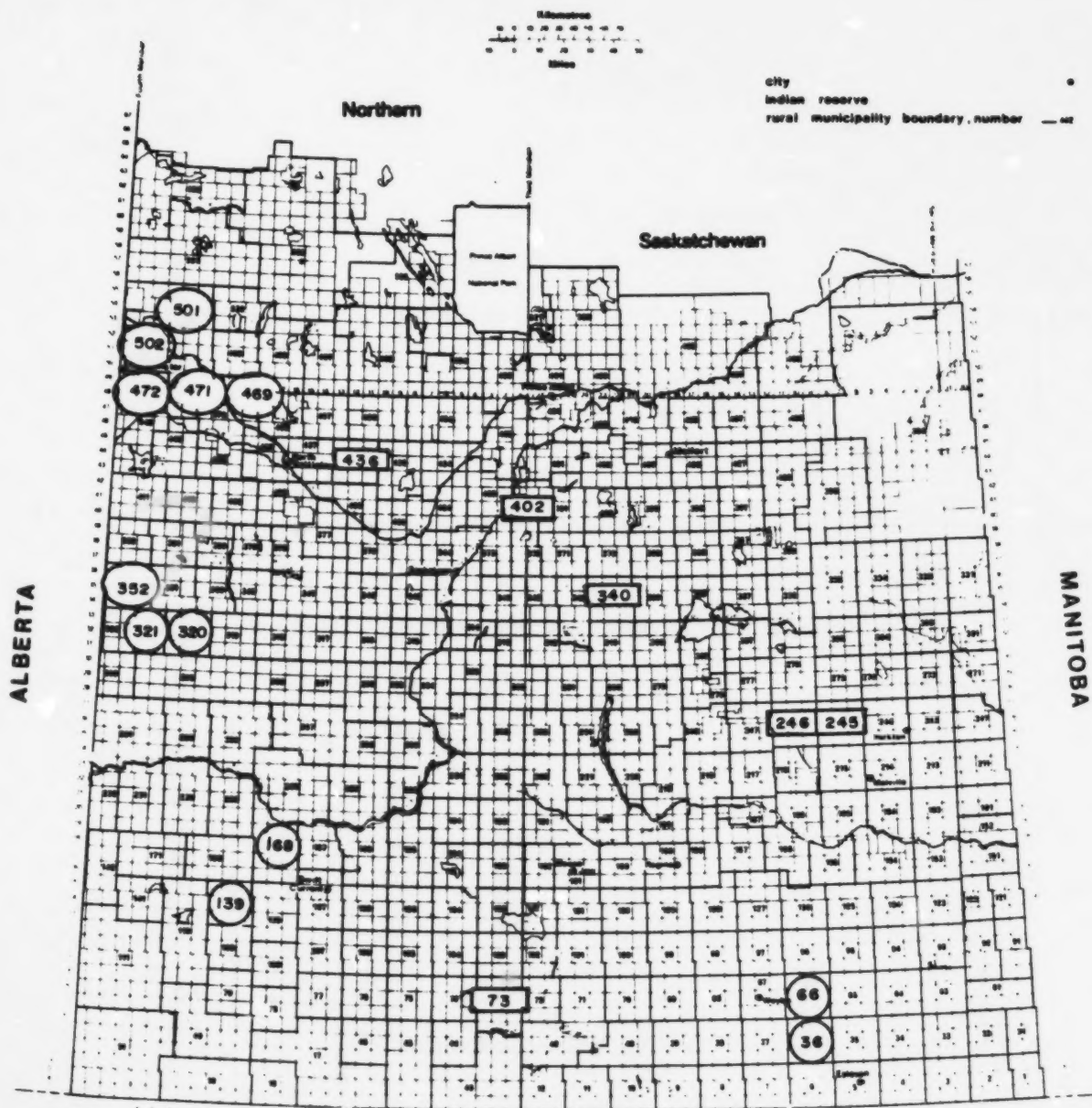


FIGURE 2.19
SOUTHERN

SASKATCHEWAN

RURAL MUNICIPALITIES



HEAVY OIL RMS

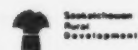
998
469
471
472
501
502

LIGHT/MED OIL RMS

36
66
139
168
320
381

AGRICULTURAL

73
245
246
340
402
436



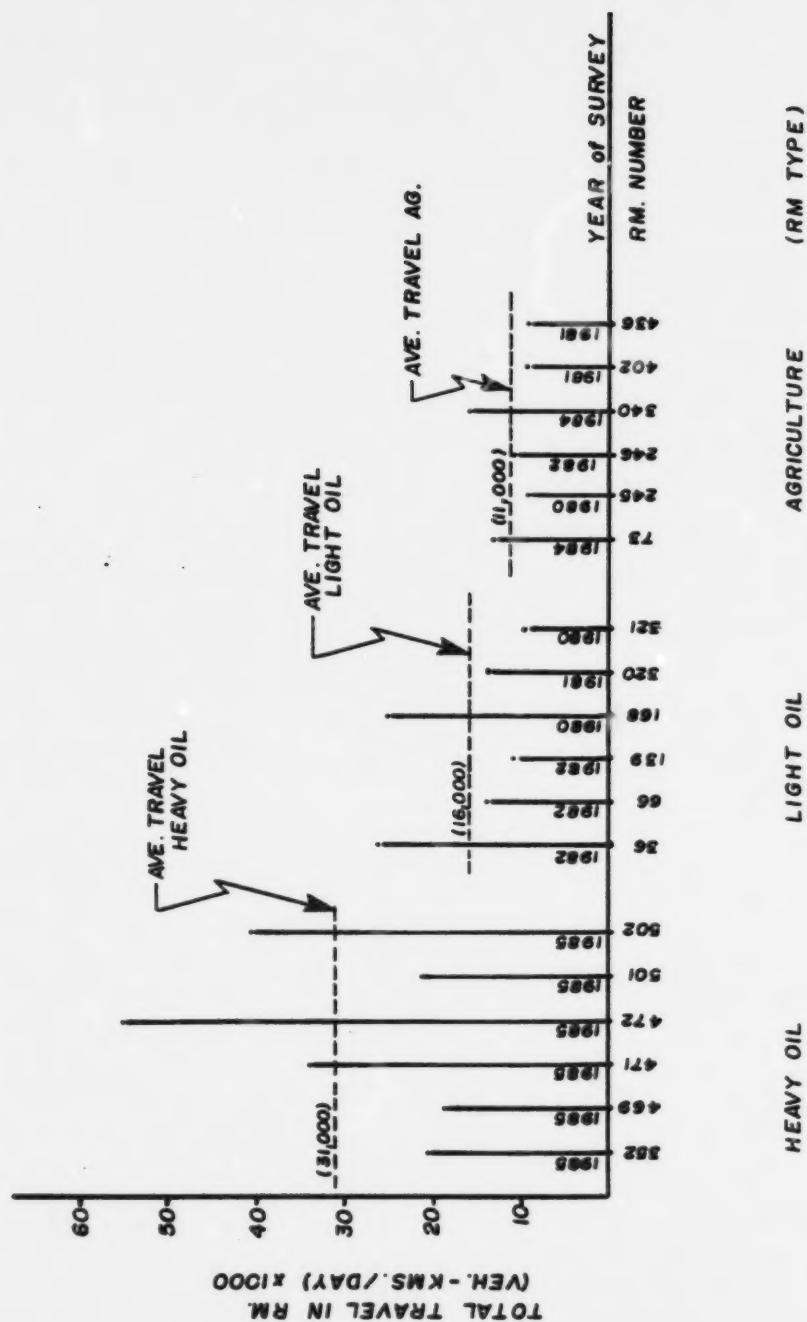
roads servicing 150 - 200 vehicles per day.

From a comparison of the above noted traffic flow maps, it can be seen that RM's with heavy oil development tend to have more roads serving larger volumes of traffic than do RM's with light/medium oil development and only agriculture.

This general conclusion is further illustrated by Figure 2.20 which plots estimates of total travel within the 18 RM's noted above. As noted from Figure 2.20, some care must be taken in making general statements respecting travel in RM's with various types of activities because while average total travel is highest in RM's with heavy oil, some of the individual RM's with light/medium oil developments have more total travel than some with heavy oil (i.e. travel in RM No. 36 and RM No. 168, RM's with light oil, exceed total travel in RM No. 352, RM No. 469, and RM No. 501, RM's with heavy oil. Similarly, total travel in RM No. 73, and RM No. 246, RM's with only agriculture, exceed the total travel in RM's No. 139 and No. 321, RM's with light/medium oil).

It is sufficient for our purposes herein to note that total travel varies substantially (i.e. by a factor of 5) between RM's with different types and levels of activities and that those RM's with high levels of oil related activity, be it heavy oil or light/medium oil, tend to have significantly higher levels of total travel. (The difference in total travel between light/medium and heavy oil areas will be

FIGURE - 2.20
TOTAL TRAVEL IN RM
VS.
RM. TYPE



Source: Rural Development

further pursued in a later section of this report.)

2.2 Growth in Traffic

The Planning and Research Branch of Rural Development undertakes traffic studies in individual RM's on a periodic basis. The six RM's in the heavy oil area that are under study here were the subject of such studies in 1981 and 1985.

The results of estimates of total travel in each of the six RM's for 1981 and 1985 are summarized in Table 2.1. As can be noted, total traffic grew from a low of 11% in RM No. 502 to a high of 59% in RM No. 471 over the five year period 1981 - 1985. In general, the growth in traffic in the heavy oil areas has been in the order of 5-10% per year. This is a very significant rate of increase in relative terms. The increase in travel provincially has tended to be in the order of 1-3% per year in recent years [3].

2.3 Composition of Traffic

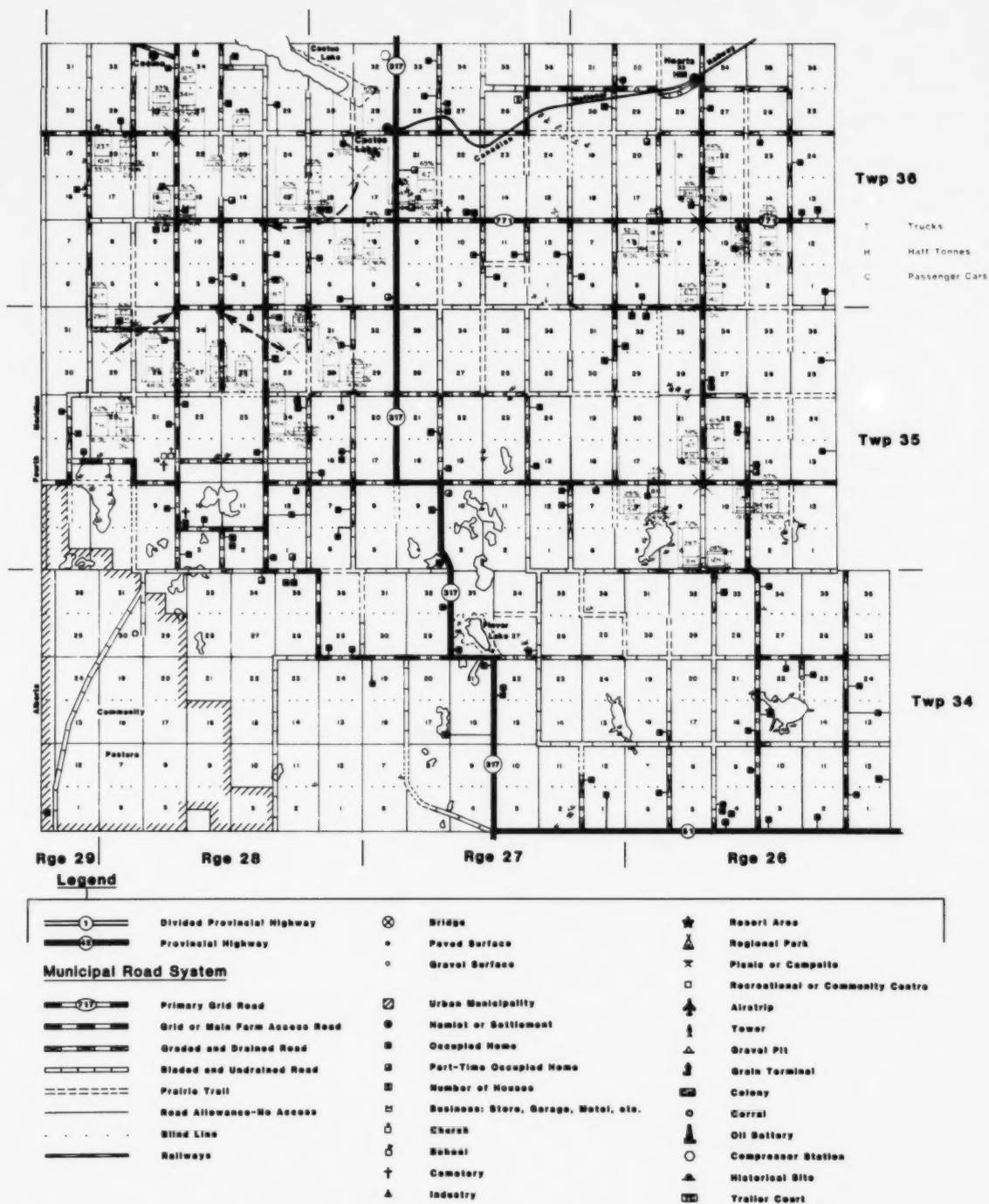
Vehicle classification surveys have also been a part of the traffic studies undertaken by Saskatchewan Rural Development within the six RM's in the heavy oil area. Figures 2.21 through 2.26 summarize the results of the 1985 classification counts. (Classification was visual, i.e. equipment, company name or vehicle etc.)

TABLE 2.1
ESTIMATED TOTAL TRAVEL

<u>RM</u>	<u>KMS OF ROAD</u> ¹	<u>1981</u>		<u>1985</u>		<u>% INCREASE</u>
		<u>AADT</u>	<u>VEH KMS</u>	<u>AADT</u>	<u>VEH KMS</u>	
352	148.8	98	14,650	136	20,197	38%
469	160.9	82	13,254	116	18,717	41%
471	221.2	96	21,347	154	34,022	59%
472	270.3	161	43,447	204	55,157	27%
501	204.3	72	14,726	102	20,808	41%
502	251.8	145	36,388	161	40,450	11%

SOURCE: Saskatchewan Rural Development
Planning and Research Branch
September 1985

1. Note: These estimates of total travel include travel on roads with typically more than 50 vehicles per day (see Figures 2.1-2.6). Therefore these estimates include most but not all travel in the RM.



Rural Municipality No. 352 Heart's Hill

VEHICLE CLASSIFICATION COUNTS

FIGURE 2.21



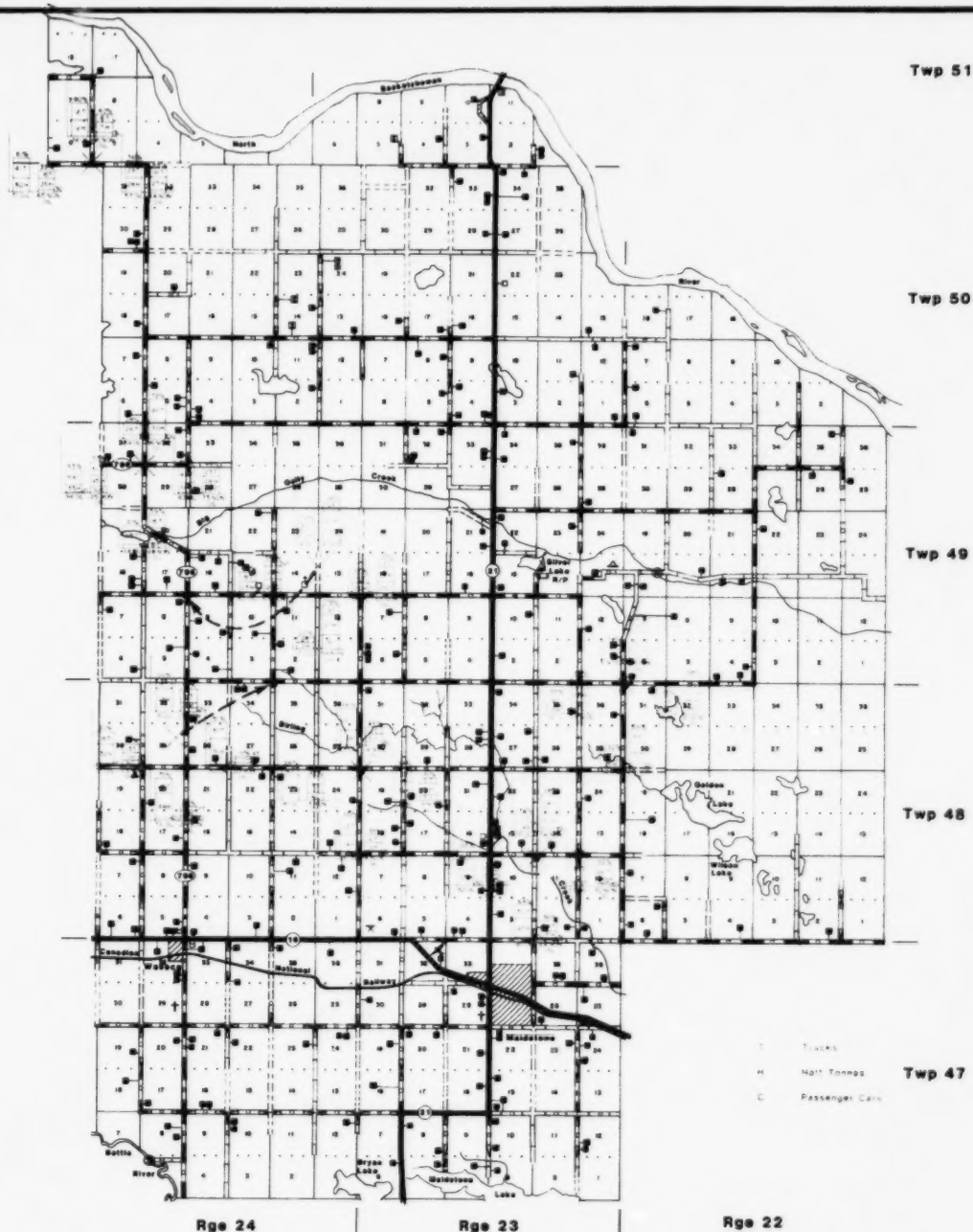
T Trucks
H Half Tonnes
C Passenger Cars

Legend

	Divided Provincial Highway		Bridge		Resort Area
	Provincial Highway		Paved Surface		Regional Park
Municipal Road System			Gravel Surface		Picnic or Campsite
	Primary Grid Road		Urban Municipality		Recreational or Community Centre
	Grid or Main Farm Access Road		Hamlet or Settlement		Airstrip
	Graded and Drained Road		Occupied Home		Tower
	Graded and Undrained Road		Part-Time Occupied Home		Gravel Pit
	Prairie Trail		Number of Houses		Grain Terminal
	Road Allowance-No Access		Business: Store, Garage, Motel, etc.		Colony
	Blind Line		Church		Corral
	Railways		School		Oil Battery
			Cemetery		Compressor Station
			Industry		Historical Site
					Trailer Court

Rural Municipality No. 469 Turtle River W. of 3rd M.
VEHICLE CLASSIFICATION COUNTS

FIGURE 2.22



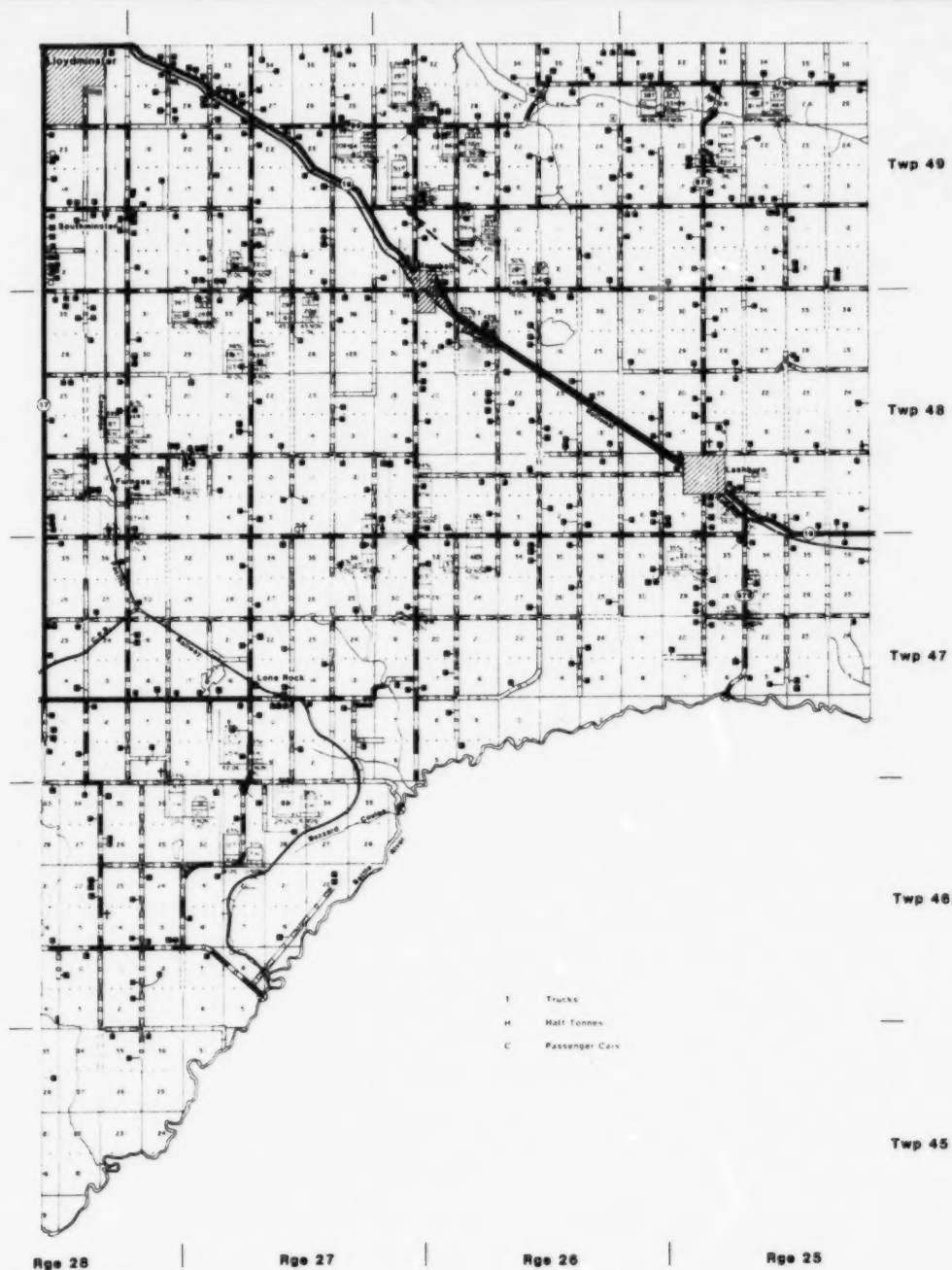
Legend

	Divided Provincial Highway		Bridge		Resort Area
	Provincial Highway		Paved Surface		Regional Park
	Municipal Road System		Gravel Surface		Picnic or Campsite
	Primary Grid Road		Urban Municipality		Recreational or Community Centre
	Grid or Main Farm Access Road		Hamlet or Settlement		Airstrip
	Graded and Drained Road		Occupied Home		Tower
	Graded and Undrained Road		Part-Time Occupied Home		Gravel Pit
	Prairie Trail		Number of Houses		Grain Terminal
	Road Allowance-No Access		Business: Store, Garage, Motel, etc.		Colony
	Blind Line		Church		Corral
	Railways		School		Oil Battery
			Cemetery		Compressor Station
			Industry		Historical Site
					Trailer Court

Rural Municipality No. 471 Eldon W. of 3rd M.

VEHICLE CLASSIFICATION COUNTS

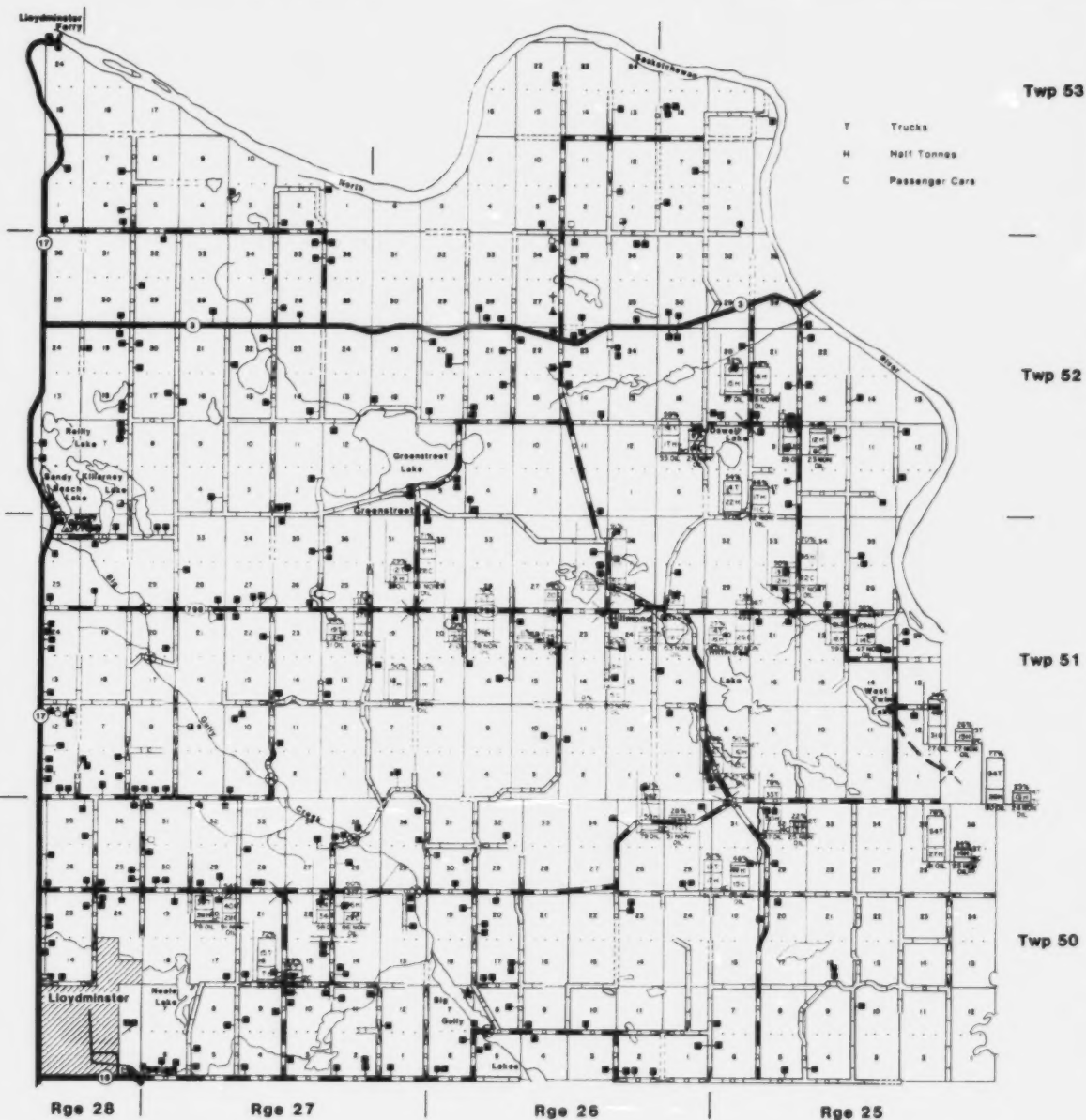
FIGURE 2.23



Rural Municipality No. 472 Wilton W. of 3rd M.

VEHICLE CLASSIFICATION COUNTS

FIGURE 2.24



Rural Municipality No. 502 Britannia

VEHICLE CLASSIFICATION COUNTS

FIGURE 2.26

As noted from Figures 2.21 through 2.26, oil related traffic accounts for 10 - 90% of the total traffic depending upon the location within these RM's. An important point to note is the high variability in the proportion of oil traffic relative to non-oil traffic for various locations. This high variability is attributable to the fact that oil development and therefore oil associated traffic is not uniformly distributed throughout the area.

Table 2.2 summarizes and Figure 2.27 illustrates the results of the classification surveys by presenting the composition of traffic by vehicle type for oil and non-oil categories averaged over each RM. As noted from Table 2.2 and Figure 2.27, the average percentage of oil related traffic varies from a low of 17% in RM No. 501 to a high of 53% in RM No. 469.

2.4 Oil Related Activities

Oil related traffic is associated with a number of different activities including [4]:

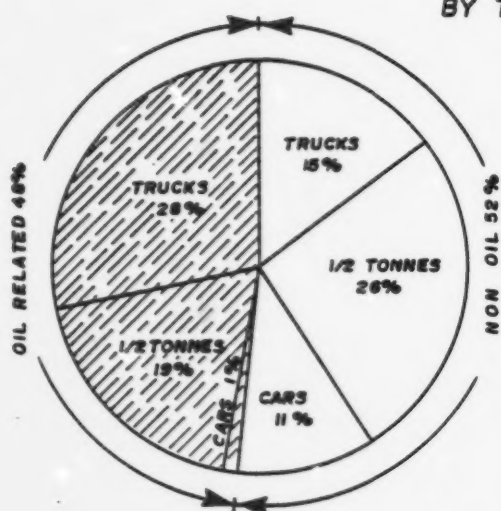
- 1) drilling
- 2) production start-up
- 3) production

TABLE 2.2
COMPOSITION OF TRAFFIC

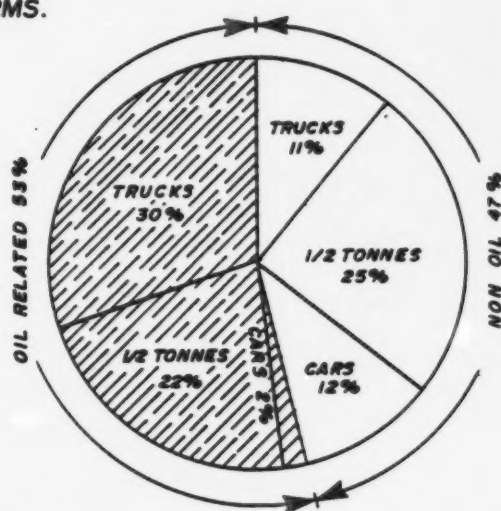
<u>RM</u>	<u>OIL</u>				<u>NON-OIL</u>			
	<u>TRUCKS</u>	<u>½ TONNES</u>	<u>CARS</u>	<u>TOTAL</u> *	<u>TRUCKS</u>	<u>½ TONNES</u>	<u>CARS</u>	<u>TOTAL</u>
352	28%	19%	1%	47%	15%	26%	11%	51%
469	30%	22%	2%	53%	11%	25%	12%	47%
471	26%	23%	1%	50%	18%	21%	11%	50%
472	18%	27%	2%	47%	11%	27%	15%	52%
501	8%	9%	0%	17%	4%	54%	26%	84%
502	23%	23%	1%	46%	8%	27%	19%	54%

* NOTE: Some rounding errors

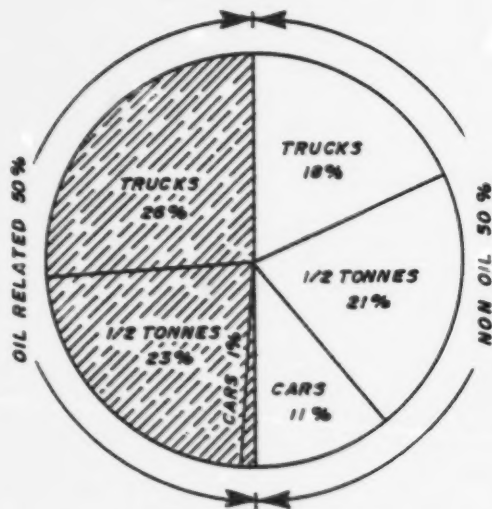
FIGURE - 2.27
COMPOSITION OF TRAFFIC
% TOTAL TRAFFIC
BY TYPE FOR RMS.



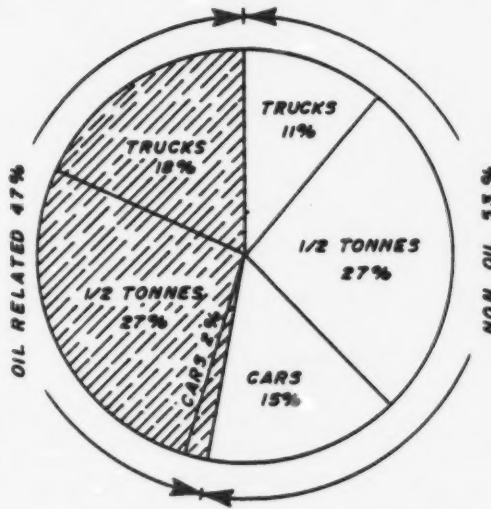
RM. 352



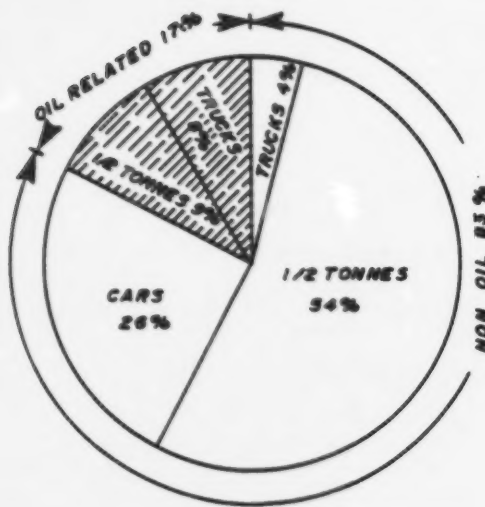
RM. 469



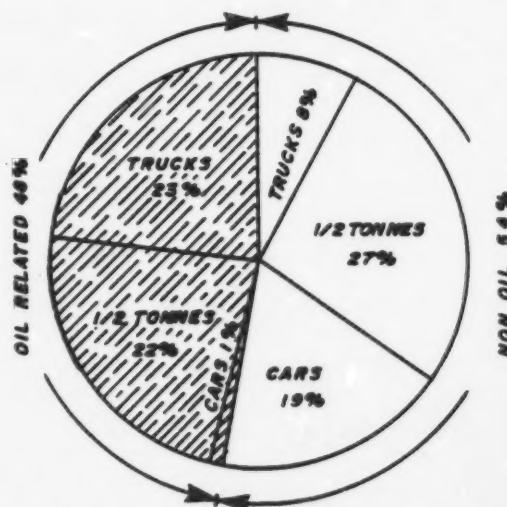
RM. 471



RM. 472



RM. 501



RM. 502

4) servicing.

Each of these activities creates a unique type and amount of traffic. Drilling activities require the movement of equipment to the site for site preparation, as well as drilling rigs, drill stem, drilling supplies including mud and water, casing, cement and well logging equipment. Once drilling is completed, all of the drilling and related equipment must be removed and the site cleaned up. This drilling activity associated with a single well generates in the order of 70-80 truckloads to and from a well. The majority (i.e. approximately 80%) of all loads are local in nature. For example, a rig would typically move from one well site to the next within the same general area. Water for drilling is typically obtained locally as is the disposal of wastes. Non-local trips would be associated with the movement of drilling mud, casing or other supplies from major supply centers to the well site.

Production start-up involves site preparation, the installation of a pumping unit along with the required production tubing and sucker rods, lease storage tanks, as well as activities related to bringing the well into production including perforation and well start-up. These activities would typically involve 10-15 truckloads, most of which would be from regional supply centers to the well sites.

Production activities generate significant long term traffic demands. This traffic is primarily associated with the movement of fluids (oil, water, gas and sand) from well sites to area cleaning plants. Also, in some cases, cleaned oil is trucked from cleaning plants to area pipeline terminals. In the order of 40%-60% of all produced fluids in the heavy oil area under study are trucked, with the remaining being flow-lined. A typical well in this area would produce between 3-5 m³ of fluids per day consisting of approximately equal volumes of oil and water.

As illustrated in Figure 2.28, approximately 200,000-250,000 cubic meters of oil has been produced per month in recent years in Area 1. (Area 1 is illustrated on Figure 2.19. It includes 5 of the 6 RM's under study, plus additional areas. Most of the oil produced in Area 1 comes from the 5 RM's under study.) Table 2.3 summarizes and Figures 2.29 through 2.34 illustrate the number and location of producing wells in each of the six RM's under study.

If one assumes that there is on average one cubic metre of water produced with each cubic metre of oil and 50% of these total fluids produced are trucked in 5 axle units with a capacity of 20 m³ per load, then there are approximately

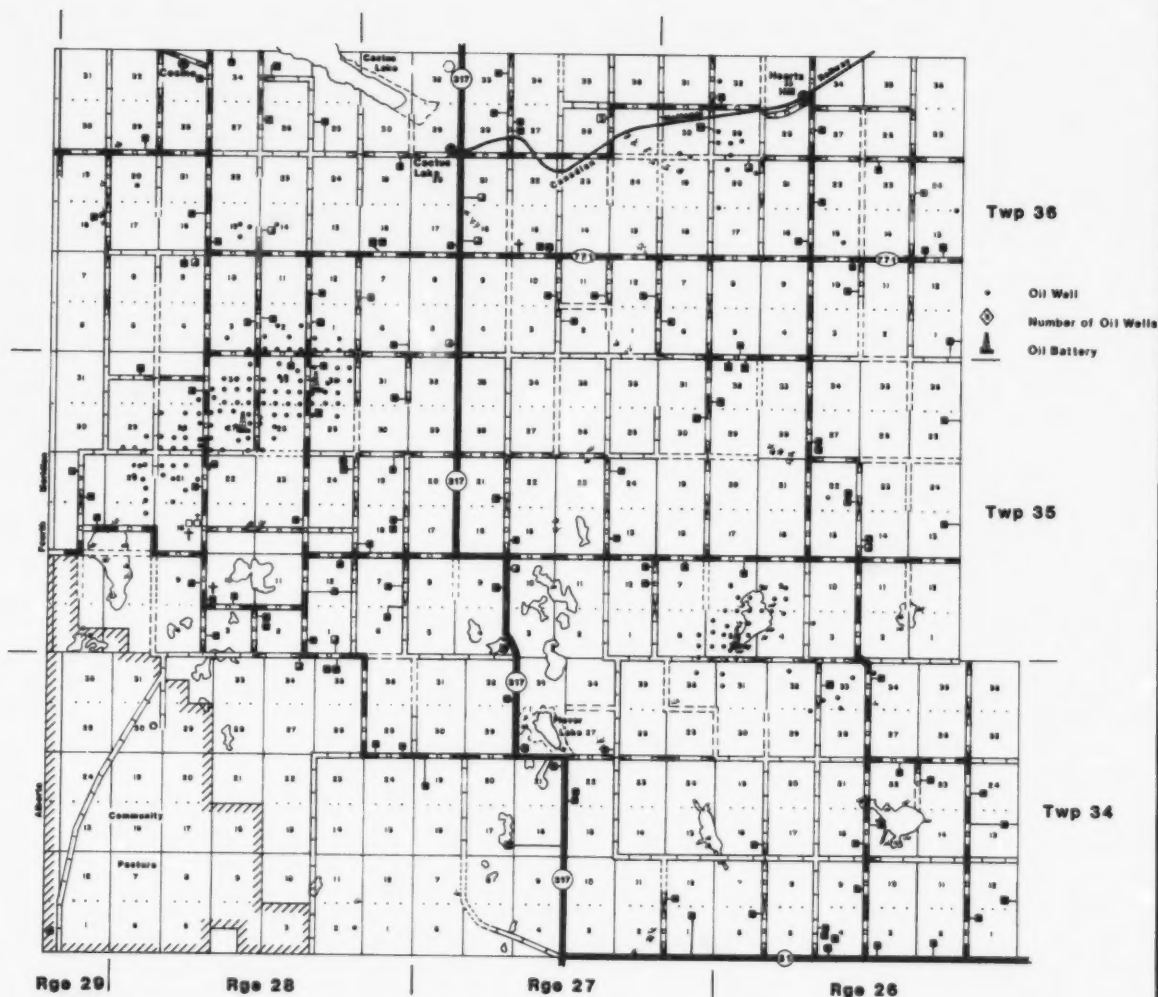
FIGURE 2.28

MONTHLY CRUDE PRODUCTION
AREA I - LLOYDMINSTER



TABLE 2.3
PRODUCING WELLS BY RM

	1979	1984	WELLS COMPLETED 1979 - 1984
RM 352	4	194	190
RM 469	3	98	95
RM 471	615	1000	385
RM 472	806	929	123
RM 501	51	261	210
RM 502	<u>407</u>	<u>568</u>	<u>161</u>
	1886	3050	1164



Rural Municipality No. 352 Heart's Hill

LOCATION OF PRODUCING WELLS

FIGURE 2.29

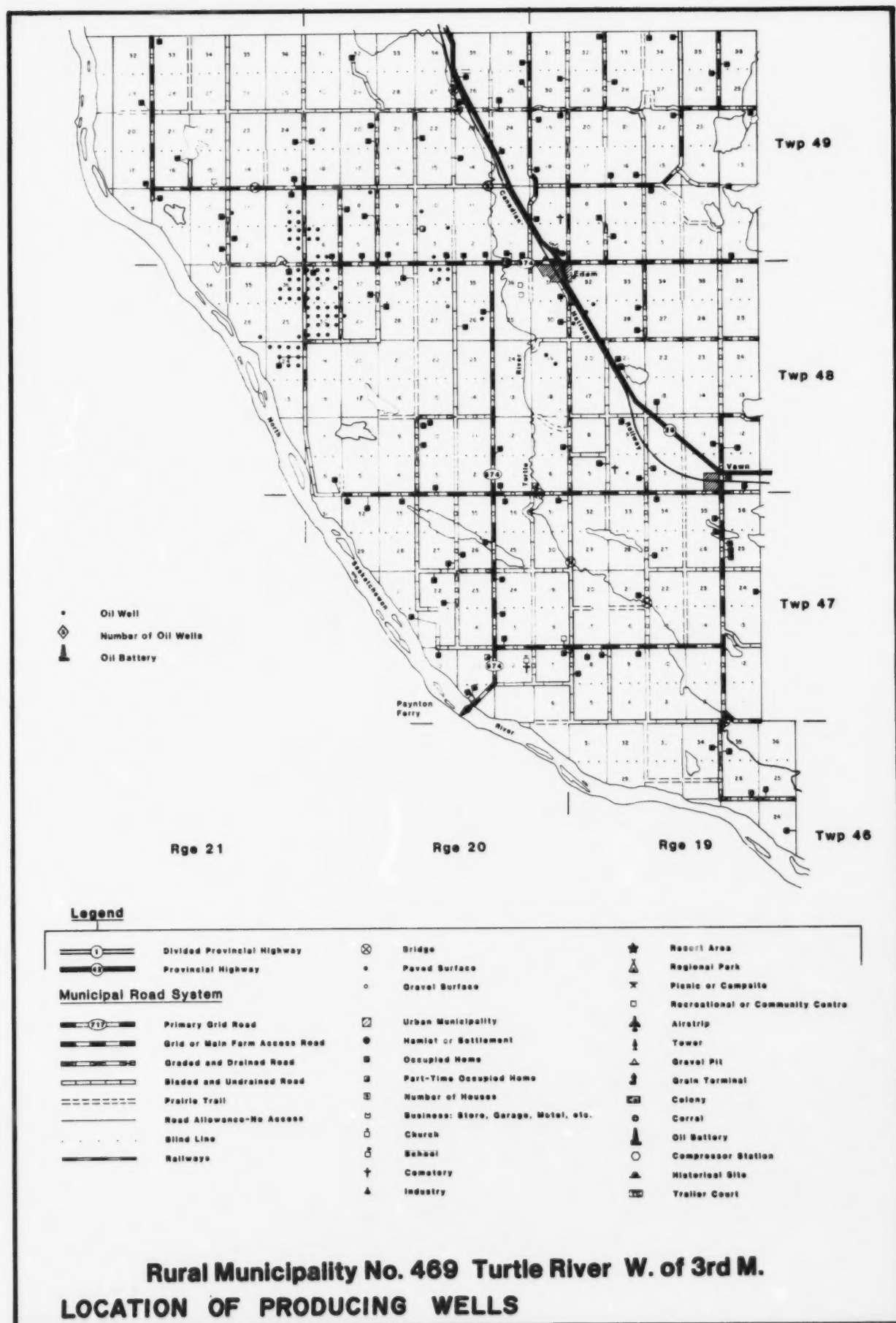
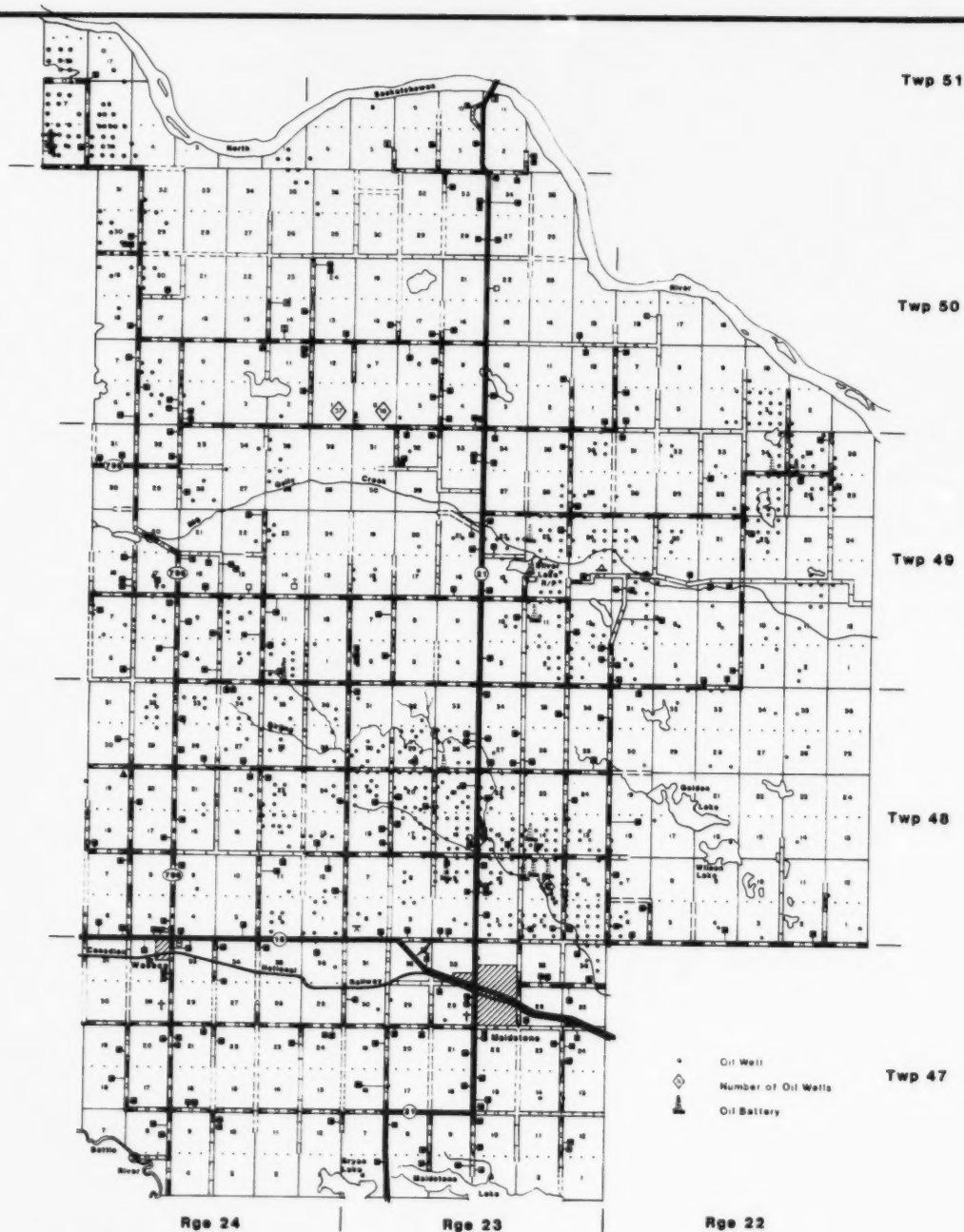


FIGURE 2.30



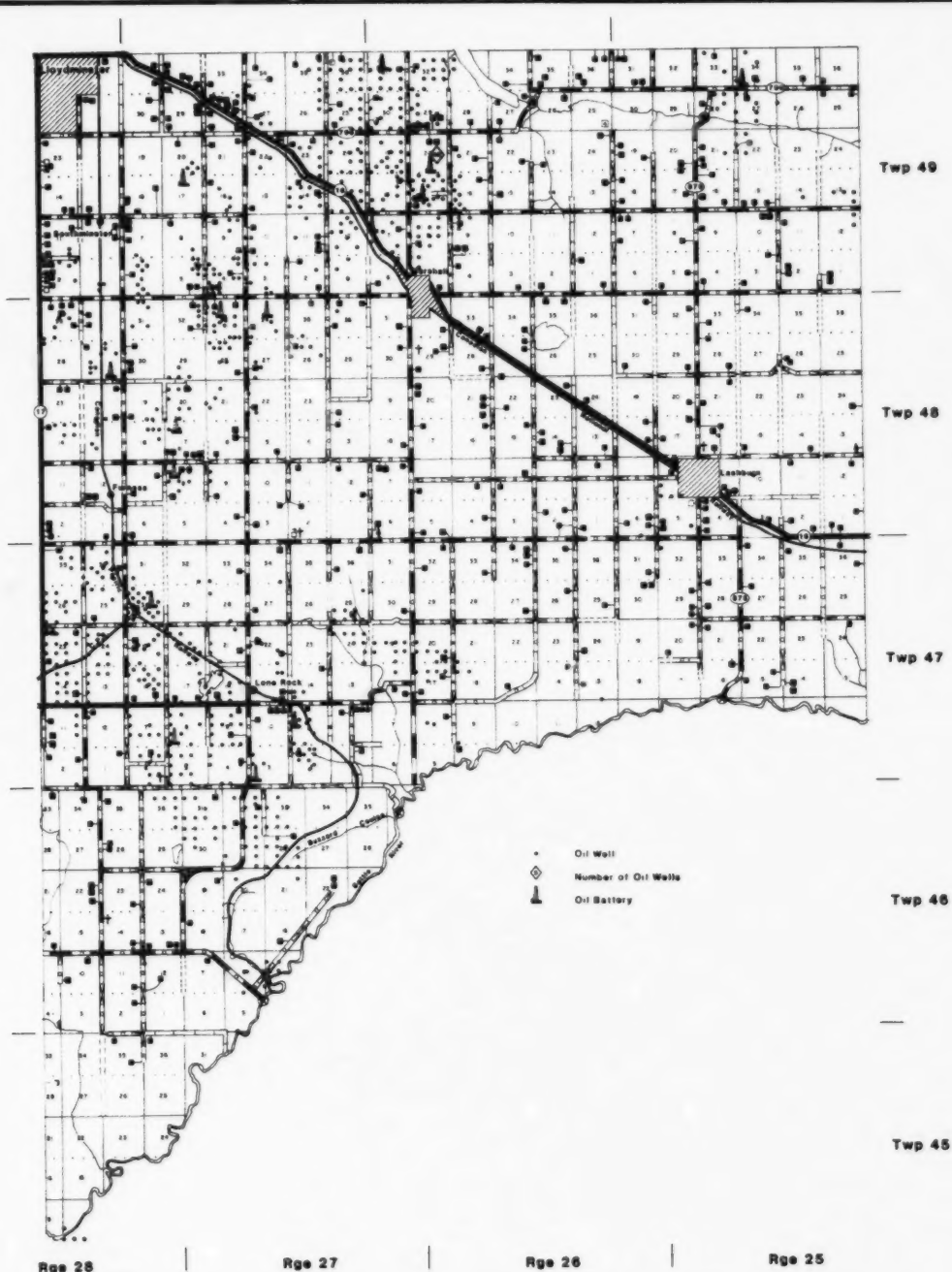
Legend

	Divided Provincial Highway		Bridge		Resort Area
	Provincial Highway		Paved Surface		Regional Park
	Municipal Road System		Gravel Surface		Picnic or Campsite
	Primary Grid Road		Urban Municipality		Recreational or Community Centre
	Grid or Main Farm Access Road		Hamlet or Settlement		Airstrip
	Graded and Drained Road		Occupied Home		Tower
	Graded and Undrained Road		Part-Time Occupied Home		Gravel Pit
	Prairie Trail		Number of Houses		Grain Terminal
	Road Allowance-No Access		Business: Store, Garage, Motel, etc.		Colony
	Blind Line		Church		Corral
	Railways		School		Oil Battery
			Cemetery		Compressor Station
			Industry		Historical Site
					Trailer Court

Rural Municipality No. 471 Eldon W. of 3rd M.

LOCATION OF PRODUCING WELLS

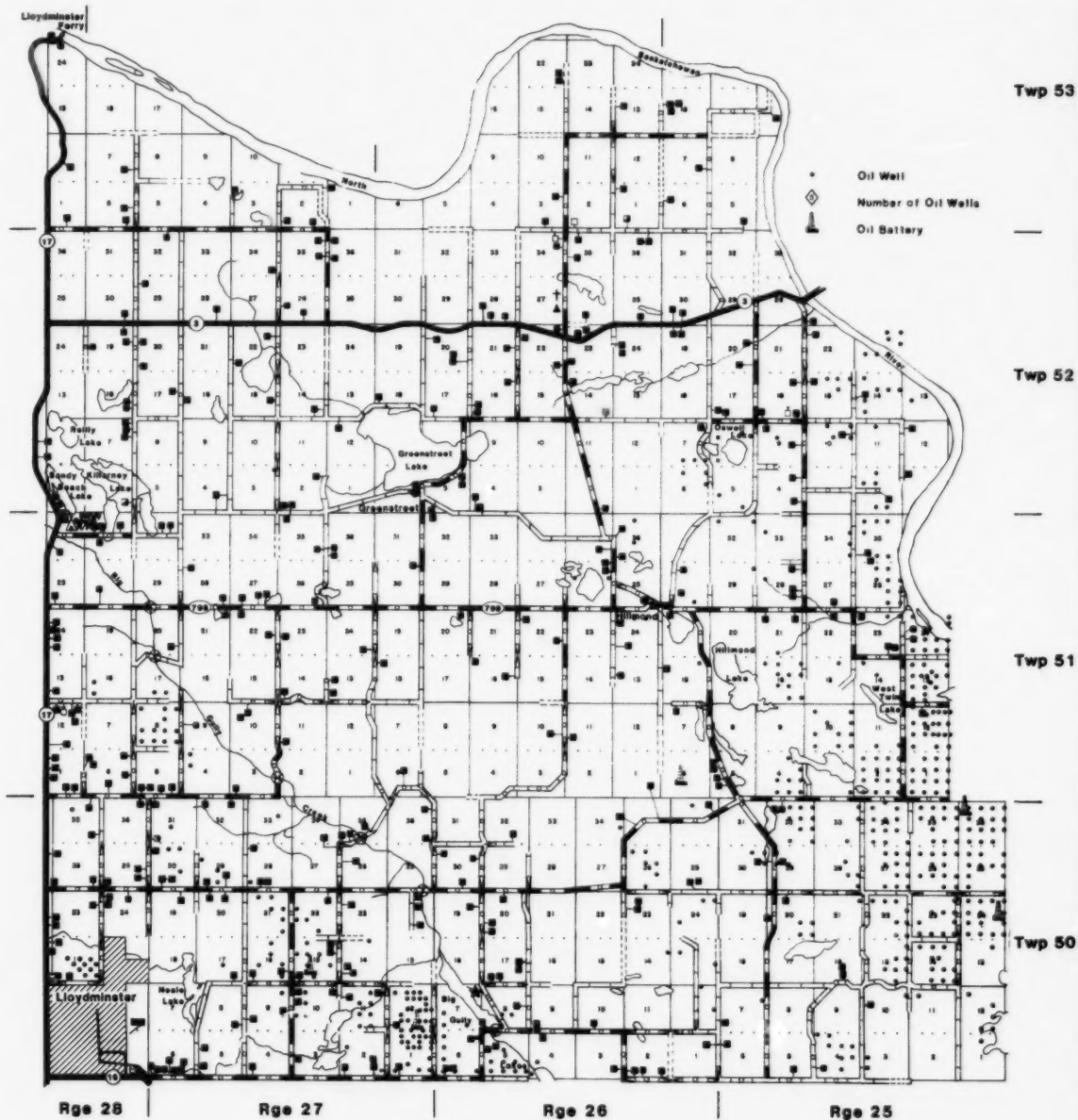
FIGURE 2.31



Legend					
	Divided Provincial Highway		Bridge		Recreational Area
	Provincial Highway		Paved Surface		Regional Park
			Gravel Surface		Picnic or Campsite
Municipal Road System					
	Primary Grid Road		Urban Municipality		Recreational or Community Centre
	Grid or Main Farm Access Road		Hamlet or Settlement		Airstrip
	Graded and Drained Road		Occupied Home		Tower
	Graded and Undrained Road		Part-Time Occupied Home		Gravel Pit
	Prairie Trail		Number of Houses		Grain Terminal
	Road Allowance-No Access		Business: Store, Garage, Motel, etc.		Colony
	Blind Lane		Church		Corral
	Railways		School		Oil Battery
			Cemetery		Compressor Station
			Industry		Historical Site
					Trailer Court

Rural Municipality No. 472 Wilton W. of 3rd M.

LOCATION OF PRODUCING WELLS



Legend

Divided Provincial Highway
Provincial Highway

Municipal Road System

Primary Grid Road
Grid or Main Farm Access Road
Graded and Drained Road
Graded and Undrained Road
Prairie Trail
Road Allowance-No Access
Blind Line
Railways

Bridge
Paved Surface
Gravel Surface
Urban Municipality
Hamlet or Settlement
Occupied Home
Part-Time Occupied Home
Number of Houses
Business: Store, Garage, Motel, etc.
Church
School
Cemetery
Industry

Resort Area
Regional Park
Picnic or Campsite
Recreational or Community Centre
Airstrip
Tower
Gravel Pit
Grain Terminal
Colony
Corral
Oil Battery
Compressor Station
Historical Site
Trailer Court

Rural Municipality No. 502 Britannia

LOCATION OF PRODUCING WELLS

11,250(1) truckloads per month, or 375 loads per day, hauled between well sites and cleaning plants in the 6 RM's under study.

The amount of fluids hauled and the origin-destination patterns of these movements are constantly changing. To illustrate, initially all fluids produced from a well may be trucked to a particular cleaning plant. As additional wells are developed in the area, the amount of trucking could increase dramatically only to cease completely when a new cleaning plant is constructed in the area and adjacent wells are flow-lined to the cleaning plant. Also, produced fluids may be hauled to one cleaning plant one month and to another the next.

The important point to note is that there is significant trucking activity associated with the production phase and that the level and pattern of truck movements are constantly changing. Concentrated truck hauls would tend to be present

-
1. $(225,000 \text{ m}^3 \text{ of oil/month} + 225,000 \text{ m}^3 \text{ of water})50\% - 20 \text{ m}^3/\text{load} = 11,250 \text{ loads/month.}$

near cleaning plants and dispersed in proportion to non-flow-lined producing wells throughout the area.

Servicing of wells also generates truck traffic. Wells are typically serviced 3 or 4 times per year with each servicing requiring 3 service trucks. In addition to the service trucks, 3 truckloads are typically required to load the well after servicing to put it back into production.

Order of magnitude estimates of the total travel within a particular RM associated with drilling, production start-up, production and servicing can be developed from the data presented above. Such estimates are developed in Table 2.4. It is important to note that the estimates in Table 2.4 are only order of magnitude with the validity of the estimates being a function of the validity of the assumptions made.

The estimates do however indicate what might have been suspected. That is, traffic associated with servicing and production activities account for the bulk of the traffic (i.e. 29% and 58% respectively).

Further insight might be gained respecting the relative amount of oil related traffic by comparing the total estimated vehicle kilometres of oil related traffic with estimates of total travel in each of the RM's. This comparison is summarized in Table 2.5.

TABLE 2.4

ESTIMATED OIL RELATED VEHICLE KILOMETRES

	PRODUCING WELLS 1984	WELLS COMPLETED 1979-1984	ESTIMATED WELLS DRILLED 1979-84 (1)		DRILLING (2)	START-UP (3)	VEHICLE KILOMETRES/YEAR		
			1979-84	AVERAGE/YEAR			PRODUCTION (4)	SERVICING (5)	TOTAL
RM 352	194	190	209	42	100,800	18,900	206,000	104,760	430,460
RM 469	98	95	105	21	50,400	9,450	104,000	52,920	216,770
RM 471	1000	385	424	85	204,000	38,250	1,060,000	540,000	1,842,250
RM 472	929	123	136	27	64,800	12,150	986,000	501,000	1,563,950
RM 501	261	210	230	46	110,400	20,700	277,000	141,000	549,100
RM 502	568	161	177	35	84,000	15,570	603,000	306,000	1,008,570
					614,400	115,020	3,236,000	1,645,680	5,611,100
					11%	2%	58%	29%	100%

(1) Assumes a 10% failure rate

(2) 80 truckloads/well x 15 km/one way trip in RM x 2 x number of wells drilled = vehicle kilometres per year

(3) 15 truckloads/well x 15 km/one way trip in RM x 2 x number of wells drilled = vehicle kilometres per year

(4) $(225,000 \text{ m}^3 \text{ oil/month} + 225,000 \text{ m}^3 \text{ water/month}) / 40\% \text{ trucked} + 3050 \text{ wells} = 59 \text{ m}^3/\text{well/month} \times 12 \text{ months} + 20 \text{ m}^3/\text{load} = 35.4 \text{ loads/well/year} \times 15 \text{ kilometres/one way trip} \times 2 = 1062 \text{ vehicle kilometres/well} \times \text{number of producing wells} = \text{vehicle kilometres in RM}$

(5) 6 truckloads/producing well/year x 15 kilometres/one way trip x 2 x number of producing wells = vehicle kilometres per year

Note: the 15 km/one way trip in an RM is assumed on the basis of a reasonable average for each trip within a particular RM. Any one total trip may exceed the 15 km, however approximately 15 km of the total is assumed to be in any one RM.

TABLE 2.5

ESTIMATED TOTAL OIL AND NON-OIL RELATED TRAVEL

	ESTIMATED OIL RELATED (1) VEHICLE KILOMETRES/YEAR	ESTIMATED TOTAL VEHICLE KILOMETRES/YEAR (2) 1985 (MILLIONS)	OIL RELATED AS % OF TOTAL (3)
RM 352	430,000	7.3	6%
RM 469	217,000	6.8	3%
RM 471	1,842,000	12.4	15%
RM 472	1,564,000	20.0	8%
RM 501	549,000	7.8	7%
RM 502	1,009,000	14.6	7%

(1) Oil related travel referred to here is only that specifically identified with drilling, start-up, production and servicing

(2) As estimated by Saskatchewan Rural Development, Planning and Research Branch, September 1985

(3) These are low compared to visual counts (see text for explanation).

From Table 2.5 it is noted that the oil related travel which is identifiable from specific oil related activities is in the order of 3-15% of total travel. This is in contrast with the results of the traffic surveys which indicate that 17%-50% of all traffic is oil related.

The obvious differences in the above are likely explained by the fact that the estimates of total oil related travel using the profiles of traffic generated is a "bare-bones" estimate. That is, there are clearly numerous oil related trips which have not been considered in the profiles. For example, visits by battery operators, the bit supplier or the welder have not been specifically identified. As such, it is reasonable to see how the estimates using the profiles could be low by a factor of 2 or 3.

On the other hand, the traffic counts and classification surveys tended to be taken at major intersections and would therefore be expected to have picked-up a somewhat disproportionately large amount of "through" traffic and therefore could be somewhat biased to the high side. These comments are not to imply that there are errors in the estimates, but rather to illustrate the limitations in the data from various sources.

A number of important observations can be made from the above. Firstly, the traffic surveys indicate that oil related travel is a significant part of total travel within

these RM's. Intuitively no one can disagree with this fact. Secondly, in terms of total travel and or total trips, the identifiable components associated with specific activities (i.e. drilling, start-up, production and servicing) are a small percent of the total. This should not be suprising because when driving around in these RM's, it is an occasion on most roads to meet a truck moving a drilling rig or a truck hauling oil. That is, on average, 1 in 10 or 1 in 20 vehicles which you would meet would be involved in such activities. In short, while there is a significant portion of total traffic which is oil-related, it is difficult to specifically categorize it from the data available.

In terms of the differences in traffic between RM's with heavy oil developments and those with light/medium oil, the primary differences would be those associated with hauling of oil during production and to a lesser extent, traffic associated with more frequent well servicing in the heavy oil areas. Also important is the relative density of wells in the heavy oil areas in relation to light/medium developments.

In spite of the obvious differences in traffic levels, one would not expect to be able to detect an obvious difference using traffic counts or estimates of total travel because these types of trips are such a small proportion relative to the total (i.e. 11,250 truckloads of produced fluids per month moving to 20-30 cleaning plants in 6 RM's amounts to 10-30 loads per plant per day, or 1-3 loads per hour per

plant). This traffic would be very sensitive to location. That is, you could observe high volumes of truck traffic on a road adjacent to a cleaning plant while observing few trucks on a road two miles away. That is, it would be more appropriate to collect data on movements into and out of cleaning plants if one were interested in oil production related truck traffic rather than to try to identify and quantify this activity using traditional traffic counts and surveys.

In order to quantify the magnitude of truck movements into particular cleaning plants, specific data was obtained from industry sources. Because of the confidentiality of this type of data, only aggregated totals for a sample of cases are reported herein. Table 2.6 summarizes these illustrative examples.

The points to note from Table 2.6 include:

- 1) quantities handled by individual cleaning plants on any given month vary from 2000 m^3 to $20,000 \text{ m}^3$,
- 2) in some cases all produced fluids are flow-lined, in other cases, 90% are trucked,
- 3) truck volumes at individual cleaning plants can vary from 40 loads per month to 750 loads per month.

TABLE 2.6
MONTHLY PRODUCED FLUID ARRIVALS AT TYPICAL CLEANING PLANTS
(m³)

<u>CLEANING PLANT</u>	<u>ALBERTA TRUCK</u>	<u>SASKATCHEWAN TRUCK</u>	<u>TOTAL TRUCK</u>	<u>FLOW-LINED</u>	<u>TOTAL</u>
1	-	1558.4	1558.4 57%	1157.4 43%	2721.8
2	-	811.4	811.4 11%	6206.9 89%	7114.6
3	-	-	-	5852.0 100%	5852.0
4	21.6	5284.8	5306.4 71%	2129.8 29%	7436.2
5	59.2	1688.2	1747.6 78%	494.7 22%	2242.3
6	-	11037.1	11037.1 55%	9013.0 45%	20050.9
7	-	-	-	24411.1 100%	24411.1
8	-	-	-	4935.7 100%	4935.7
9	-	15102.6	15102.6 80%	3727.6 20%	18830.2
10	801.9	6543.3	7345.2 64%	4120.6 36%	11465.8
11	-	1161.6	1161.6 90%	122.9 10%	1284.5

Source: Industry Representatives

The above suggests that there can be very significant numbers of truck trips associated with the movement of produced fluids, however because of the highly varied types of operations and the dynamic nature of these activities over time, it is impossible to generalize. As such, it would be most productive to deal in case specific terms.

2.5 Future Traffic

Traffic in the heavy oil area can be expected to increase as the intensity of development increases. Much of the heavy oil development which is expected to take place in the next 5 years is expected to be further development in terms of additional wells and enhanced oil recovery (EOR) projects within established areas, plus some extension and definition of fringe areas.

Table 2.3 summarizes the number of producing wells by RM as of 1984. Table 2.7 summarizes the details related to EOR projects within Area 1 as of November 5th, 1984. Table 2.8 summarizes estimates of future well drilling and EOR projects for the 1985-1990 period.

From Table 2.7 it is noted that Area 1 had 318 EOR production wells as of November 1984. Table 2.8 illustrates that 500-700 wells are expected to be drilled in Area 1 per year in the 1985-1990 period, approximately 25% of these are

TABLE 2.7
ENHANCED OIL RECOVERY PROJECTS IN SASKATCHEWAN

AREA 1	OPERATOR	PROJECT TYPE	DATE OF FIRST INJECTION	LOCATION	PROJECT AREA (HA)	WELL SPACING (HA)	NUMBER OF WELLS PRODUCTION	NUMBER OF WELLS INJECTION
<u>LLOYDMINSTER</u>								
Aberfeldy	Husky Oil	In Situ Wet Combustion	7/69	1,12-50-27 W3	219	4	45	9
Aberfeldy	Husky Oil	Steamflood with Steam Stimulation	2/81	20-49-26 W3	50	1	44+	9
Celtic	Mobil Oil	Suspended in Situ Combustion Currently Evaluating Steamflood and Stimulation	10/80	10-52-23 W3	55	2	29	1
Epping **	Cdn. Reserve	Caustic Waterflood	6/79	36-47-28 W3	40	8		
Eyehill	Murphy Oil	In Situ Dry Combustion with Steam Stimulation	6/80	15,16-40-28 W3	101	2 & 4	24+	9
Golden Lake S. (Sparky)	Husky Oil	In Situ Wet Combustion	7/68	11,12-48-23 W3	166	4	36+	5+
Golden Lake S. (Waseca)	Husky Oil	Air/Oxygen In Situ Wet Combustion	4/82	14-48-23 W3	144	4 & 8	17	2
Golden Lake S. (Waseca)	Husky Oil	Oxygen Enriched Air In Situ Wet Combustion	7/82	14-48-23 W3	13	1.3	10	2
Lone Rock *	Cdn. Reserve	Steamflood with Steam Stimulation		11-47-27 W3	32	2	13	3
Neota	Canterra Energy	Steam Stimulation with Steam Drive	7/74	23,24-46-18 W3	21	1	18	3

TABLE 2.7

ENHANCED OIL RECOVERY PROJECTS IN SASKATCHEWAN

AREA	1	OPERATOR	PROJECT TYPE	DATE OF FIRST INJECTION	LOCATION	PROJECT AREA (HA)	WELL SPACING (HA)	NUMBER OF WELLS PRODUCTION INJECTION
(continued)								
Pikes Peak		Husky Oil	Steam Stimulation	7/81	6-50-23 W3 1-50-24 W3	55	1	53 -
Silverdale		** Murphy Oil	In Situ Wet Combustion	8/73	25-48-28 W3 30-48-27 W3	36	4	
Silverdale		* Home Oil	Water Alternating Gas	-	6-49-27 W3	97	8	10 3
Tangleflags		* Husky Oil	In Situ Wet Combustion with Steam Stimulation	-	18-51-24 W3 13-51-25 W3	56+	4	19+
								318 46

* Projects under construction

** Projects suspended

SOURCE: Saskatchewan Energy and Mines
Petroleum and Natural Gas Division
November 5th, 1984

TABLE 2.8
SASKATCHEWAN HEAVY OIL AREA DRILLING PROJECTIONS
1985 - 1990*

<u>YEAR</u>	<u>TYPE</u>	<u>LLOYDMINSTER</u>		
		<u>Comp.</u>	<u>Dry</u>	<u>Total</u>
1985	Conventional	408	112	520
	EOR	<u>150</u>	<u>-</u>	<u>150</u>
	Total	558	112	670
1986	Conventional	411	119	530
	EOR	<u>100</u>	<u>-</u>	<u>100</u>
	Total	511	119	630
1987	Conventional	403	117	520
	EOR	<u>105</u>	<u>-</u>	<u>105</u>
	Total	508	117	625
1988	Conventional	397	118	515
	EOR	<u>55</u>	<u>-</u>	<u>55</u>
	Total	452	118	570
1989	Conventional	376	114	490
	EOR	<u>175</u>	<u>-</u>	<u>175</u>
	Total	551	114	665
1990	Conventional	368	112	480
	EOR	<u>65</u>	<u>-</u>	<u>65</u>
	Total	433	112	545

* One year Royalty/Tax Holiday in effect throughout the forecast period

SOURCE: Saskatchewan Energy and Mines
 Petroleum and Natural Gas Division
 November 5th, 1984

expected to be EOR projects and the remaining 75% conventional wells. In total, it is anticipated that an additional 4,000 - 5,000 producing wells will be added in Area 1 between 1985 - 1990. This, when added to the existing 3,000 wells, will more than double the number of producing wells in the area by 1990.

If the above noted projections related to heavy oil come to pass, there will be increased demands placed upon the roadway infrastructure in coming years. The demands associated with drilling and start-up can be expected to continue at least at levels experienced in recent years (i.e. 500 wells per year). Activities associated with production and servicing are a function of the total number of producing wells and can therefore be expected to increase substantially.

Some caution must be exercised when estimating the increase in production related truck activities (i.e. hauling produced fluids to cleaning plants). There may be substantially more such traffic, or there may be somewhat less depending on the nature of actual development. To illustrate, as the amount of oil produced in an area increases, there is need for more cleaning plants. These are often located in areas of concentrated development (i.e. near an EOR project) with produced fluids being flow-lined thereby reducing the amount of trucking. Also, the cleaned oil will usually be flow-lined as opposed to trucked to pipeline terminals if volumes justify such. In short, within the scope of this

project, it is difficult to comment on the exact character and magnitude of future production related trucking activities. It is however possible to put upper and lower bounds on the likely limits of demand. It is unlikely that production associated trucking activities would be less than current levels, but it is also unlikely that it would increase in direct proportion to total numbers of producing wells (i.e. double), because as density of wells increases, a higher proportion is likely to be flow-lined.

The general level of traffic is largely related to the general level of activity. As a result of the fact that the general level of development and production of heavy oil in Area 1 can be expected to continue at least at the pace of the last two years and may be at a somewhat accelerated pace, the general level of traffic can be expected to be at least at recent levels and likely at somewhat higher levels. In lieu of anything better, the recent growth rate in traffic of 5-10% per year could be used as a guide (1).

1. This is a Q & D (Quick and Dirty) estimate and should be regarded as such.

2.6 Summary

The available data clearly indicates that the RM's in which extensive heavy oil development is taking place experience significantly higher levels of traffic than RM's with light/medium oil development or only agriculture. Traffic volumes in RM's with intense heavy oil development experience 200 - 400 vehicles per day on many roads with volumes exceeding 500 vehicles per day on some roads. These volumes compare with those on some provincial highways.

The levels of traffic demands tend to be associated with the general level of activity as opposed to the type of development. That is, while there is increased truck traffic in RM's with heavy oil because some of the produced fluids must be hauled as opposed to flow-lined, this would not explain the difference in levels of traffic between RM's with heavy oil developments relative to those with light/medium oil. The difference in total traffic is more attributable to the more intense type of development and therefore the requirements for more intense management and servicing. Put simply, an RM with 1000 producing oil wells would be expected to have more oil related traffic than an RM with 100 wells. This is (nearly) independent of type of oil development.

Traffic in the 6 RM's under study which have heavy oil development has grown at a rate of 5-10% per year for the past 3 years. This compares with 1-3% for travel in the

province generally.

The traffic in the RM's with extensive heavy oil development experience traffic demands which are approximately 50% oil related and 50% non-oil related. Large trucks hauling oil make up only a small percent of total traffic or total vehicle kilometres of travel in RM's with heavy oil development. This traffic tends to be concentrated on a few roads, most notably those near cleaning plants or pipeline terminals and is subject to dramatic changes over time.

Since total traffic tends to be related to the general level of activity and the number of producing wells is expected to increase by 500 - 700 per year, bringing the total producing wells in Area 1 from 3,000 in 1984 to approximately 7,000 by 1990, traffic in the RM's with heavy oil can be expected to continue at least at recent levels, and will likely grow substantially.

Chapter Three: Road Costs

3.1 Introduction

As previously noted, the overall objective of this project was to assess the impact of traffic associated with heavy oil development on regional highways and municipal roads. In particular, the project was to identify the incremental impact of heavy oil traffic relative to existing base traffic, as well as that typically associated with light/medium oil development.

The previous chapter provided some insight into the magnitude and characteristics of traffic in RM's with heavy oil development and to a lesser extent, those with light/medium oil development and only agriculture.

This chapter will build on Chapter 2 by providing insight into the performance of roadway structures when subjected to traffic as well as to quantify the costs associated with the construction and maintenance of various types of roads when subjected to various levels and types of traffic.

3.2 Performance of Roads

In order to understand how roadway structures perform under traffic loading, it is necessary to understand the parameters involved and the inter-relationships of these variables. The

discussion herein will initially focus upon the performance of subgrades and gravel surface roadways. This discussion will then be extended to consider thin and heavy duty pavement structures. This focus is appropriate because we are primarily concerned with the structural performance of gravel surface and thin pavement roads within the study area.

Figure 3.1 presents a conceptual model for the performance of gravel roads. From Figure 3.1, it is noted that the major determinants respecting performance of gravel roads are:

- 1) loading,
- 2) soil type, and
- 3) soil conditions.

The observable phenomena by which the adequacy of the performance of a gravel road is judged relate to the smoothness and integrity of the surface, and include:

- 1) pot holes,
- 2) washboard ridges,
- 3) rutting,
- 4) soft spots, and
- 5) subgrade failures.

The actions taken to maintain or restore acceptable performance include:

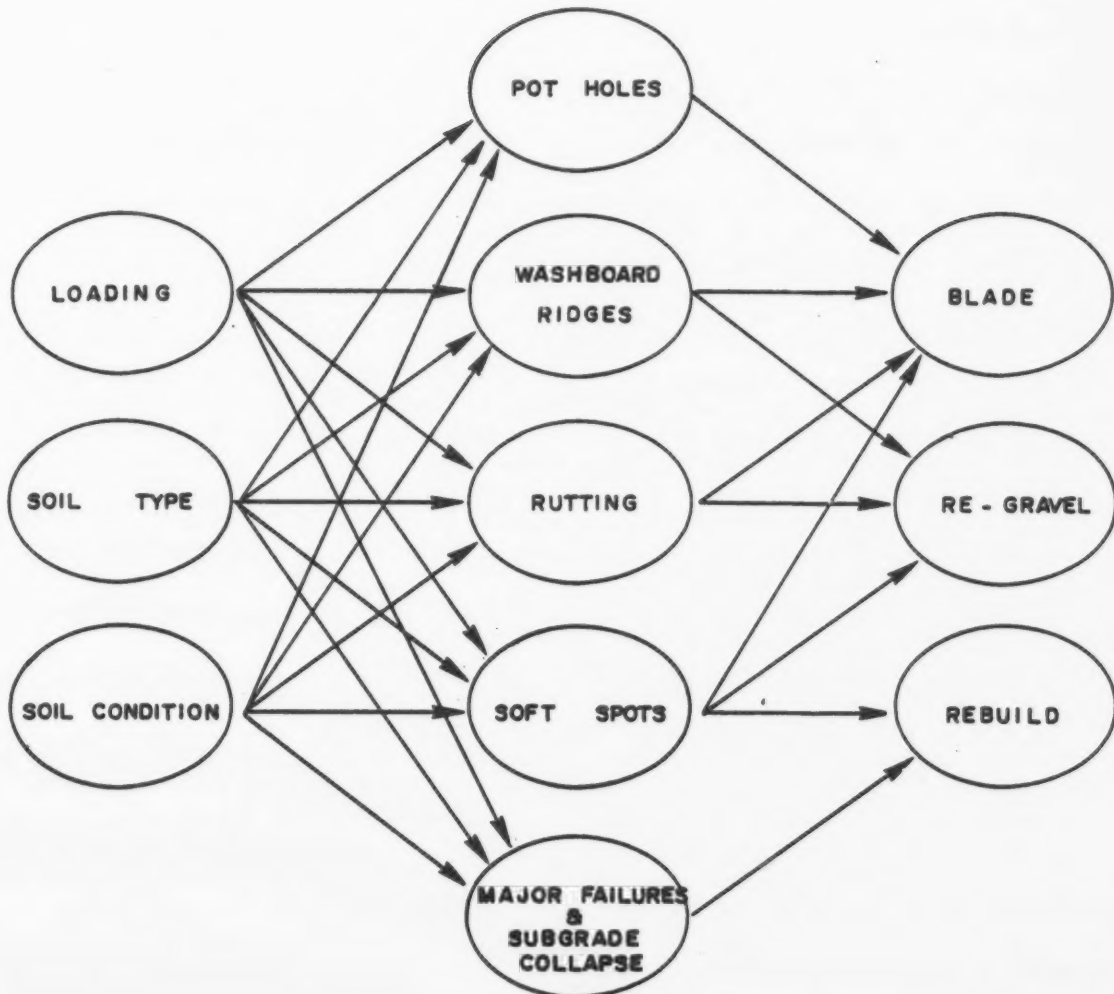
FIGURE 3.1

ROAD PERFORMANCE MODEL FOR GRAVEL ROADS

MAJOR
DETERMINANTS

OBSERVABLE
DISTRESS

REMEDIAL
ACTION



- 1) blading,
- 2) regravelling, and
- 3) reconstruction.

The significance of the above parameters and their inter-relationships in determining the performance of gravel roadways can be illustrated by the following.

Gravel surfaces can often deteriorate rapidly under certain conditions when subjected to a large number of heavily loaded trucks (i.e. gravel haul). (As will be noted later, the important parameters respecting heavily loaded trucks are axle weight and tire pressure. Gross vehicle weight of heavy trucks is much less important in terms of road impact, however very important relative to long span bridges. Therefore, hereinafter, heavily loaded trucks refers to axle weight and not necessarily gross vehicle weight.) This deterioration often occurs on roads which would have performed satisfactorily for many years if subjected to only automobiles, light pick-up trucks and the occasional large truck. The observed deterioration takes the form of pot holes, ruts, washboarding, soft spots, etc. Collectively, these forms of distress result in roadway roughness, loss of gravel and general distortion of the roadway in terms of flattening of the cross-section, roller coaster profiles, etc. Maintenance required includes repeated blading, regravelling, and in some cases, excavation and replacement of subgrade materials and/or complete reconstruction.

The performance of gravel roads is primarily determined by the performance of the subgrade, because the loads are applied directly to the subgrade. (As will be noted later, this is also the case for thin pavements, whereas in heavy duty pavements, the loads are applied to the pavement structure and then in turn transmitted to the subgrade.)

In the case of gravel roads, the observation of various forms of distress occurring in the subgrade can be summarized as follows.

- 1) Small numbers of light loads (automobiles and pick up trucks) have only minimal affect on the road surface and any roughness that does develop can be quite easily removed by routine maintenance (i.e. blading occasionally).
- 2) Heavy trucks produce a dramatic deterioration of the road surface.
- 3) The degree of distress increases rapidly with frequency of heavy loads.
- 4) The distress manifests itself as noted above in the form of pot holes, washboarding, ruts, soft spots and failures.
- 5) The form of distress in (4) above result collect-

ively in roadway roughness, loss of gravel and distortion of the roadway cross-section and profile.

- 6) The degree of distress varies seasonably being worse when wet weather prevails.
- 7) Most severe conditions develop during springtime.
- 8) The problems recur annually.
- 9) Some problem areas "heal" more or less permanently, but these are rare.
- 10) The problem may diminish as the roadway dries and hardens under prolonged traffic.
- 11) Distress appears to occur randomly across and along the roadway but is more severe in the outer wheel path.
- 12) The problem is more severe with some soil types than others.
- 13) The problem is more severe in poorly drained areas.
- 14) A newly constructed road will often not support heavily loaded gravel trucks even though it carried heavy machinery during construction. This problem

occurs during paving operations where numerous subgrade failures have to be repaired while base course and paving materials are being hauled to the site over the newly constructed grade.

In spite of the apparent complexity of the distress patterns, there are really only three variables involved, namely load, soil type, and soil conditions. All observed phenomena can be explained in these terms.

Loading must be defined in terms of intensity, loading patterns and frequency of application. Soil type is most strongly influenced by clay content. (In the study area, the soil is mainly glacial till, a reasonably homogeneous material with predictable composition.) For a given soil type, two factors describing soil condition influence soil behavior. These are soil moisture and density, or degree of compaction. The variables of loading and soil conditions can be simulated in the laboratory under controlled conditions, where each can be examined independently. Some basic work has already been done in this connection which can be directly applied to this study. [5]

3.2.1 Loading

Contact tire pressure controls the intensity of stress applied to the subgrade soil. The applied stress in the subgrade (as measured in pounds per square inch, psi) cannot

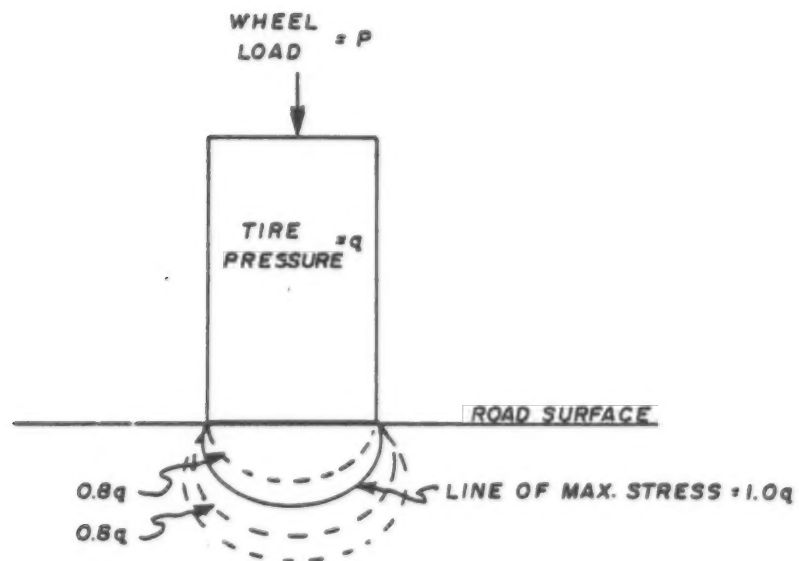
exceed the tire pressure (in psi). The higher the tire pressure, the higher the stress applied to subgrade. The inter-relationship between tire pressure and the stress created in the soil beneath the tire is illustrated in Figure 3.2.

If the stress created in the soil by the pressure in the tire exceeds the "strength" of the soil, the soil will "fail". This "failure" results in a displacement or movement of soil particles relative to each other which in turn results in a loss of density or compaction and is observed as a softening of the soil.

The load on each wheel controls the depth of stress penetration. As illustrated in Figure 3.3, the heavier the wheel load, the greater the depth of maximum stress. For very light wheel loads (i.e. 500 kgs per wheel) such as with automobiles or pick up trucks, the maximum stress (i.e. equal to the tire pressure of say, 207 kN/m^2 - 30 psi) is restricted to the upper 20 to 50 mms of the subgrade, whereas the maximum stress imparted by a truck tire inflated to 690 kN/m^2 - 100 psi and supporting a 4500 kg load may penetrate 200 - 300 mms into the subgrade.

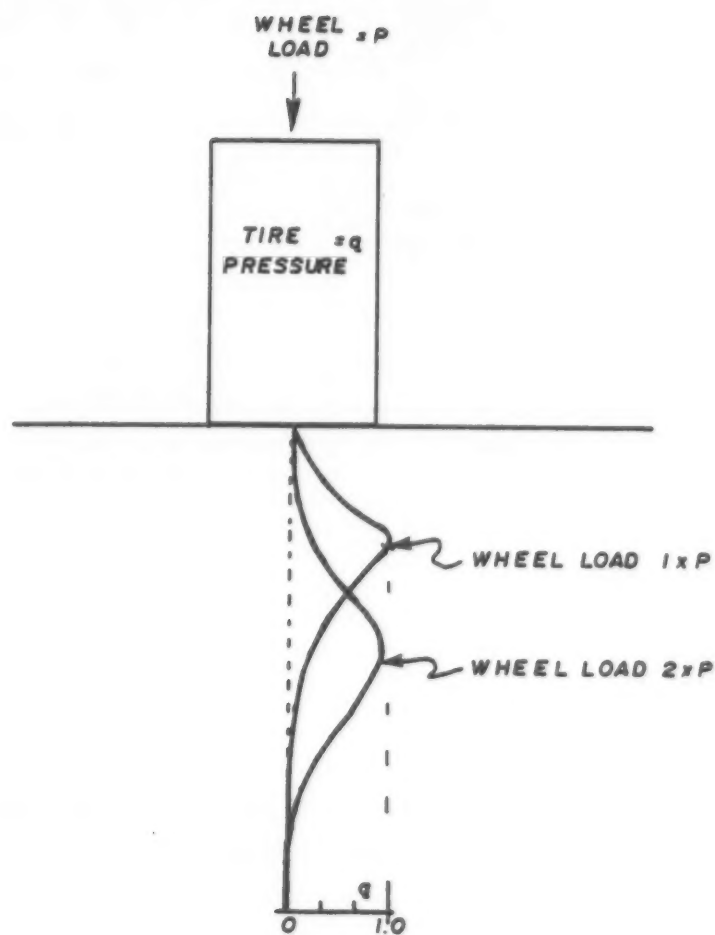
In the case of low pressure tires and light loads (i.e. automobiles and light trucks), the stress imparted to the soil will only rarely exceed the soil strength, therefore no displacement takes place and the road surface remains firm

FIGURE - 3.2



DISTRIBUTION OF STRESS CREATED IN SUBGRADE SOIL AS A
FUNCTION OF TIRE PRESSURE.

FIGURE 3.3



INTENSITY OF STRESS IN SOIL ON CENTRELINE BELOW TIRE
FOR CONSTANT PRESSURE q FOR INCREASING WHEEL LOAD.

and smooth. If the stress imparted by lightly loaded vehicles does exceed the strength of the soil, any displacements of soil will be very near the surface (i.e. within 20-50 mms) and will result in only small and shallow pot holes.

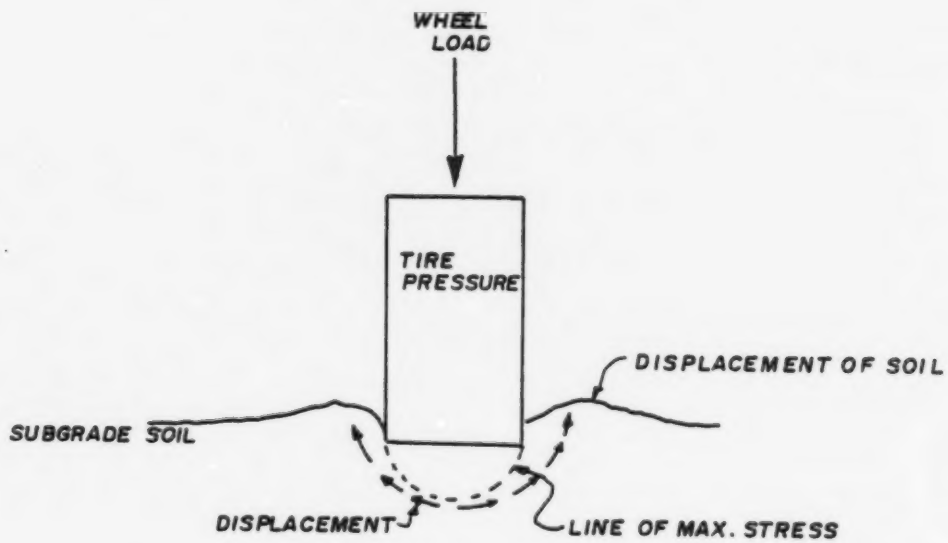
As the tire pressures and axle loads are increased (i.e. heavily loaded large trucks), the imparted stresses are increased in magnitude and the maximum stresses occur at greater depths within the subgrade. If these maximum stresses exceed the strength of the soil, displacements of soil occur at greater depth, the result being larger and deeper pot holes and rutting. This mechanism of displacement is illustrated in Figure 3.4.

3.2.2 Soil Conditions

A given soil type has a certain resistance to applied stress (i.e. strength) for a fixed water content and density. In reality, these two factors vary under field conditions. The data shown in Figures 3.5 and 3.6 illustrate how soil strength is affected by variations in water content and density. For soil conditions typically found in the study area, strength is most sensitive to changes in water content and less sensitive to changes in density.

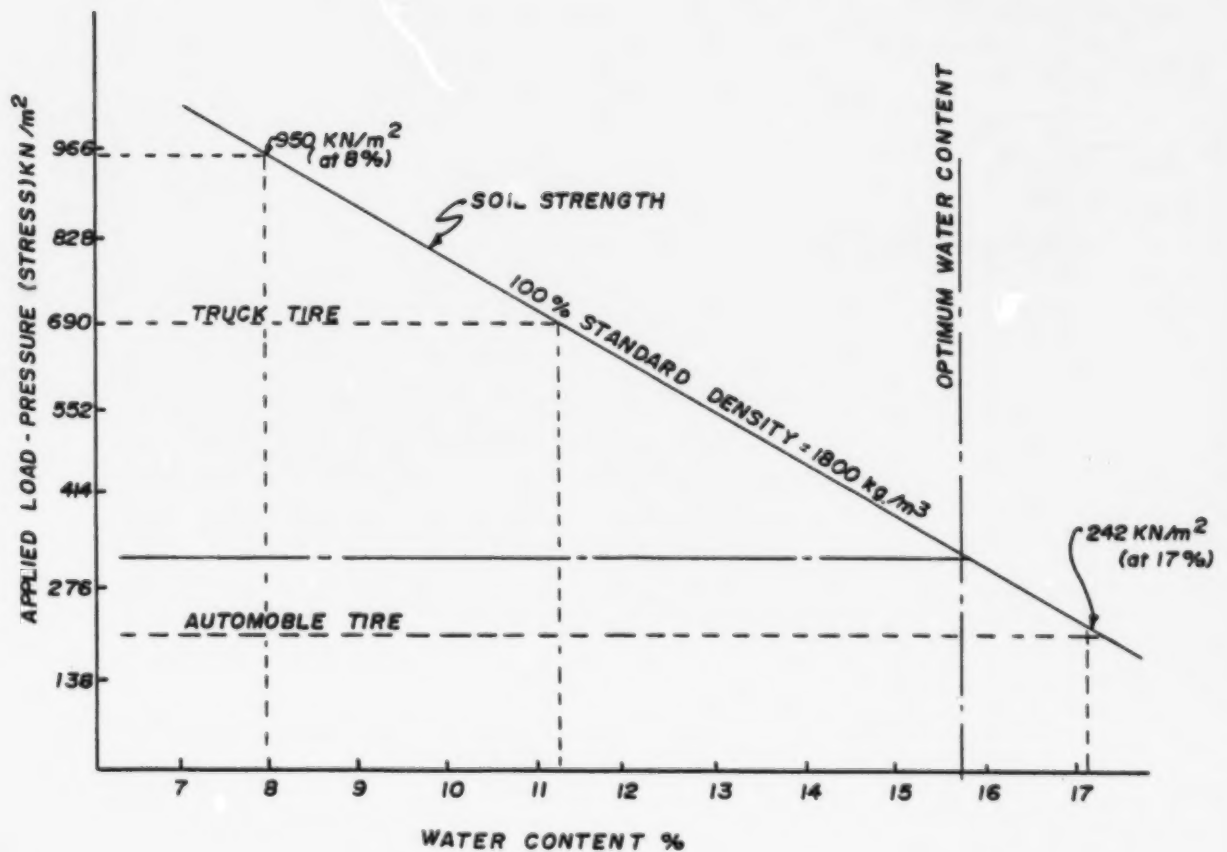
Figure 3.5 illustrates that a soil compacted to 100% standard density (i.e. 1800 kg/m^3 - 112.2 lb/ft^3 for the soil under

FIGURE 3.4



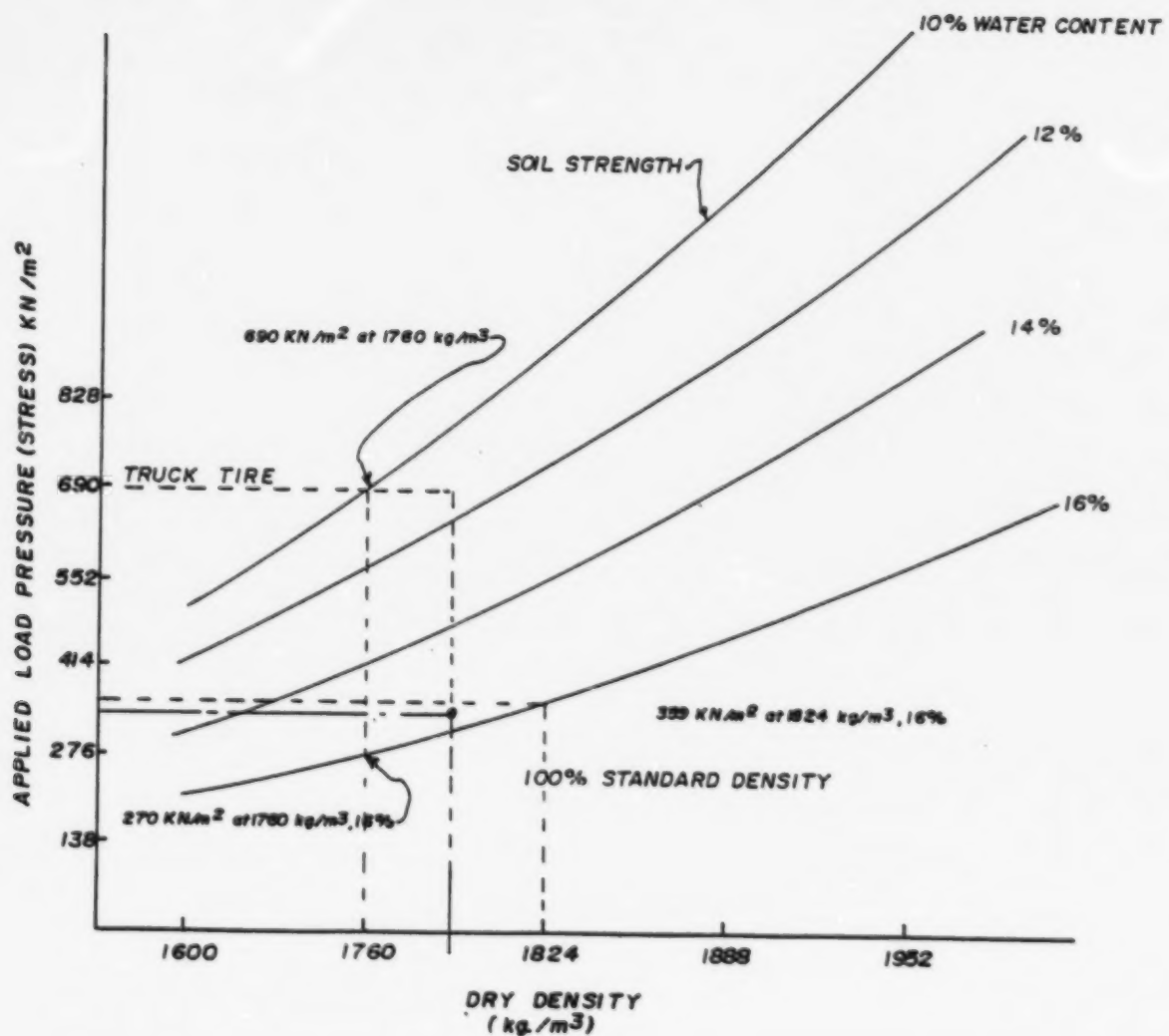
MECHANISUM OF DISPLACEMENT OF SOFTENED SOIL
CAUSED BY STRESS IN SUBGRADE. (CREATED BY TIRE
PRESSURE) EXCEEDING "STRENGTH" OF SOIL.

FIGURE 3.5



STRENGTH OF GLACIAL TILL
(FAILURE AT LESS THAN 10 LOAD APPLICATIONS)

FIGURE- 3.6



STRENGTH OF GLACIAL TILL
(FAILURE AT LESS THAN 10 LOAD APPLICATIONS)

consideration) would have a strength of 950 kN/m^2 at a water content of 8% and a strength of 240 kN/m^2 at 17%. Put another way, this soil compacted to 100% standard density would be expected to be able to support an automobile tire inflated to 207 kN/m^2 as long as the moisture content of the soil were 17.2% or less.

On the other hand, this soil could only support a truck tire inflated to 690 kN/m^2 if the water content were less than 11.4%. That is, if the moisture content of the soil exceeded 11.4% (i.e. in the spring or due to extended wet periods), trucks would be expected to cause pot holes and rutting. This problem would be increasingly severe as the moisture content increased. An important point to note is the fact that it would not be uncommon to find moisture contents of soils within the subgrades in the study area exceeding 11.4% and therefore truck traffic would be expected to cause pot holes and rut the roadways.

Figure 3.6 illustrates that the soil under consideration would have a strength of 270 kN/m^2 at a density of 1760 kg/m^3 and a water content of 16%, whereas the strength would be 359 kN/m^2 at 1824 kg/m^3 / 16% water content and 690 kN/m^2 at 1760 kg/m^3 / 10% water content. This figure illustrates that soil strength is more sensitive to moisture content than density within normal ranges. Further, strength is more sensitive to increasing soil density for soils at lower water content (i.e. slope of curves for varying water content).

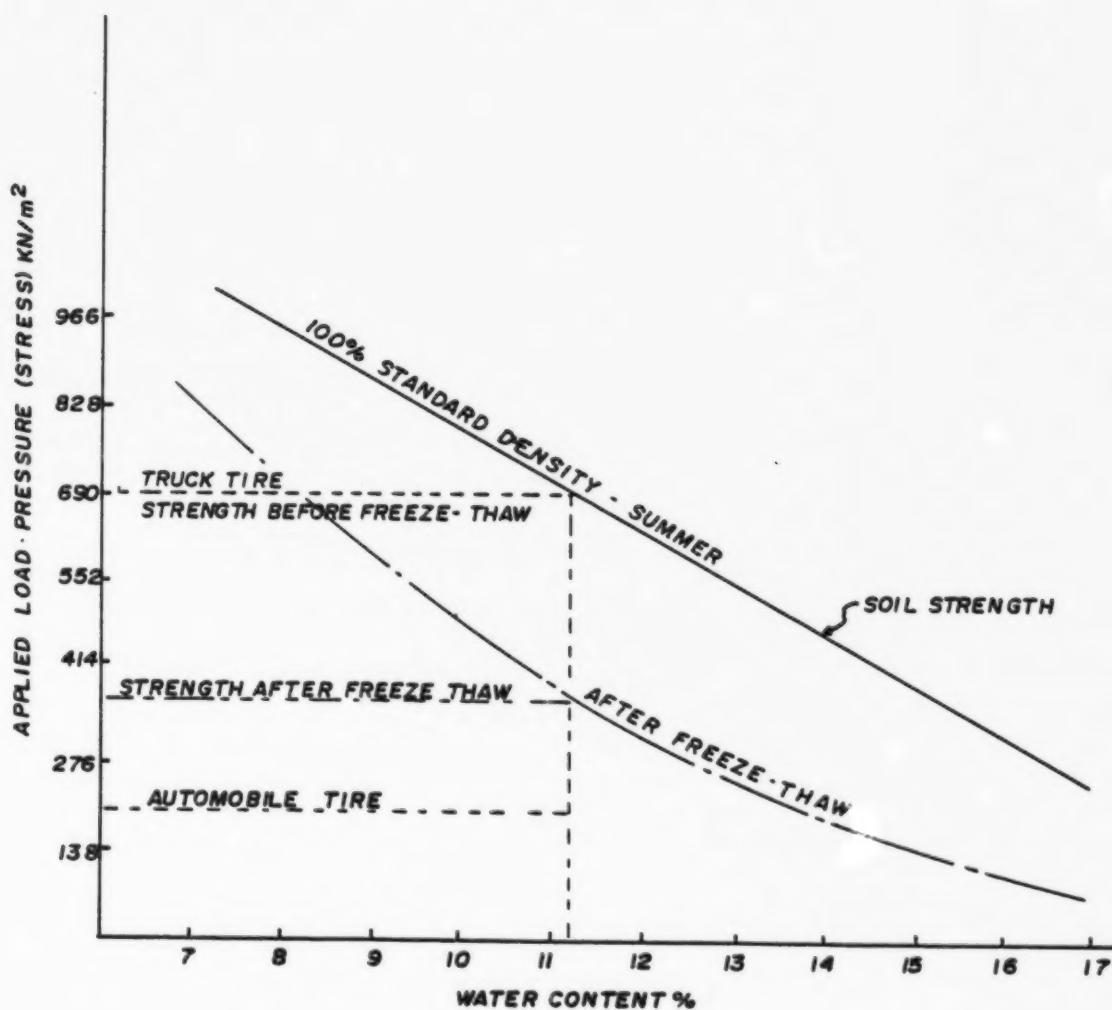
Freezing and thawing have a profound effect on reducing soil strength. Freezing and thawing have an effect upon the micro-structures of the soil which in turn affects its strength. This reduction in strength with freezing and thawing is illustrated in Figure 3.7. This effect is most sensitive to water content. As can be seen from Figure 3.7, a soil at 11.4% water content compacted to 100% standard density which could be expected to support a 690 kN/m^2 truck tire before being subjected to freeze-thaw cycles would not be expected to be able to support such loads after being exposed to freeze-thaw.

The results shown in Figures 3.5 through 3.7 are from simulated laboratory tests [5]. Samples were placed in pressurized cells and subjected to repeated dynamic loads simulating stresses similar to those imparted by a moving wheel. As illustrated in Figure 3.8, it was found that the strength of soils decrease with an increasing number of repetitions of applied loads. That is, the soil will break down at lower stresses for a greater number of repetitions. For example, at 690 kN/m^2 , a soil might break down at 10 repetitions. The same soil in the same condition (i.e. density and water content) would break down at 552 kN/m^2 after 1000 repetitions.

3.2.3 Typical Field Conditions

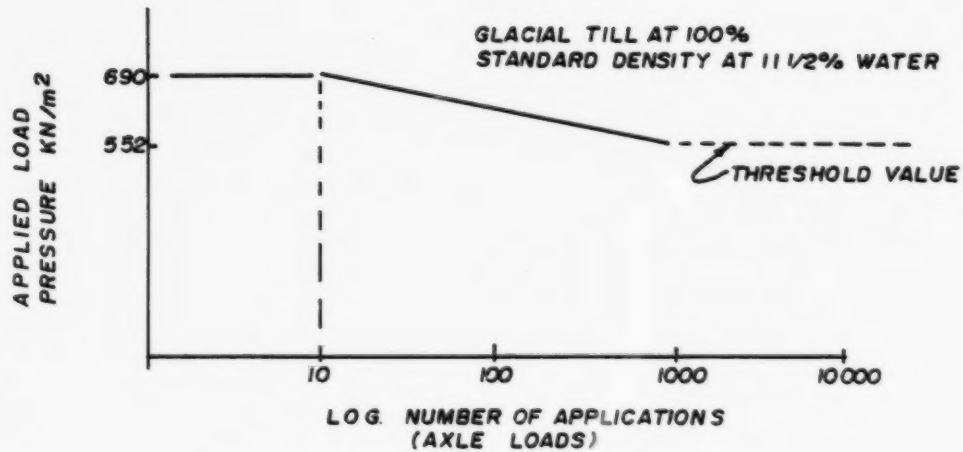
The data shown in Figures 3.5 through 3.7 are for a range of

FIGURE 3.7



STRENGTH OF GLACIAL TILL BEFORE AND
AFTER 4 FREEZE-THAW CYCLES
 (FAILURE AT LESS THAN 10 LOAD APPLICATIONS)

FIGURE 3.8



NOTE - THRESHOLD IS MAX. STRESS WHERE FAILURE WILL NOT OCCUR
REGARDLESS OF NUMBER OF LOAD APPLICATIONS.

REDUCTION IN "STRENGTH" OF SOIL CAUSED
INCREASING NUMBER OF LOAD APPLICATIONS

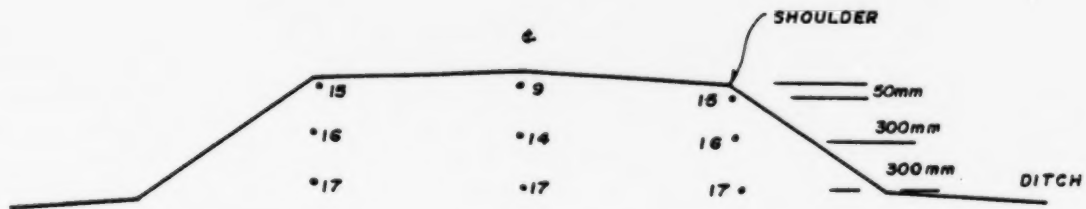
conditions typically found in the field in Saskatchewan.

Figures 3.9 and 3.10 illustrate how moisture content and density might be expected to vary within a typical roadway subgrade. The direct condition and the highest density occur near the surface and near the centre-line of the roadway. Moisture content increases with depth and distance from the centre-line (i.e. near shoulders). Overall moisture content varies with the position of the roadway cross-section relative to surrounding terrain (i.e. higher moisture contents in low areas etc). Densities tend to decrease with depth and distance from the centre-line of the roadway.

Strength profiles for a particular section of roadway subgrade can be determined by combining information relating soil strength, water content and density. For example, 50 mms below the centre-line where the moisture content is 9% and the density is 105% of standard density, the strength would be 828 kN/m^2 for the soil under consideration. One metre below the surface, the moisture content may increase to 17% and decrease in density to 90% with a resulting strength of only 242 kN/m^2 . In a similar manner, the moisture content may be 15% and the density 95% with a resulting strength of 345 kN/m^2 near the shoulder of the roadway.

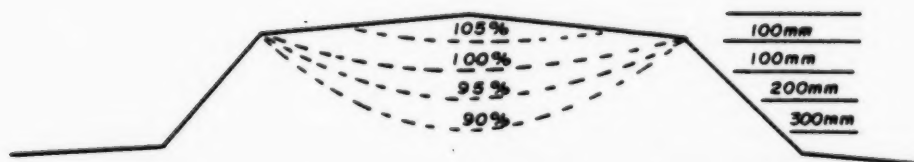
The importance of the above becomes immediately obvious in that the soil at the surface on the centre-line can support a truck with very high tire pressure (i.e. 690 kN/m^2) whereas

FIGURE - 3.9
N.T.S.



DISTRIBUTION OF MOISTURE IN GRAVEL OR OIL SURFACE ROAD
DURING DRY SUMMER WEATHER.
(FOR "STRENGTH" COMPARISONS SEE FIG. 3.5, 3.6 & 3.7)
APPROXIMATE VALUES INTERPRETED FROM OTHER STUDIES.

FIGURE - 3.10
N.T.S.



DISTRIBUTION OF DENSITY IN PERCENT OF
STANDARD DENSITY (112.2 lb/ft³)
NUMBERS ARE APPROXIMATE ONLY

the soil deeper in the subgrade or near the shoulders cannot. Therefore, for any given axle load and tire pressure, one would expect most failures to tend to be near the shoulders. As total loads increase and tire pressures are maintained, more soft spots would be expected to occur deeper within the subgrade and nearer the centre-line of the roadway. Similar observations would be expected respecting the development of soft spots as tire pressures were increased. In this way, it can be seen that both tire pressure and total wheel load have to be considered.

3.2.4 Observed Phenomena

Using the above concepts respecting loading, soil type and soil conditions as the governing controls for subgrade performance, all types of observed stress phenomena can be explained as follows.

- 1) Light loads imparted by automobiles and light trucks do not adversely affect most gravel roads during normal weather conditions because low tire pressures and low total loads do not result in stresses within the subgrade which exceed the strength of the soil.
- 2) Heavy trucks have a dramatic affect because very little of the subgrade soil has sufficient strength to withstand high tire pressures and heavy wheel loads.

- 3) The degree of distress increases with increasing number of trucks because strength decreases for an increasing number of repetitions.
- 4) Pot holes occur when the imparted stresses result in localized displacement and softening of the soil under the wheel near the surface.
- 5) Washboarding occurs when the imparted stresses result in displacement of surface materials ahead of the wheel, creating a bulge or ridge.
- 6) Ruts occur when the imparted stresses result in lateral displacement of surface material. As the depth of displacement increases, the severity of the rutting increases.
- 7) Soft spots occur when the imparted stresses result in displacement of material relatively deep within the subgrade.
- 8) Major failures occur when high moisture content occurs throughout the subgrade and the passage of heavy wheel loads at high tire pressure cause high stresses deep within the subgrade. Large displacements are observed in all directions.
- 9) Loss of gravel is caused primarily by softening of

the subgrade allowing wheels to force the gravel into the soft soil. (Note that an application of $125 \text{ m}^3/\text{km}$ results in about 10-15 mm of gravel on the surface of a typical municipal road. Therefore, in order to "accumulate" the 200-300 mms of gravel required to support truck traffic, 120 m^3 per km would have to be applied each year for 16 to 25 years.) (Some gravel is also thrown off into the ditch by traffic, and lost into the ditches during maintenance operations including blading and snow plowing.)

- 10) Distortion of the driving surface is caused by softening and displacement associated with high tire pressure and heavy axle loads.
- 11) Degree of distress varies seasonably because resulting changes in moisture cause corresponding changes in soil strength.
- 12) Most severe conditions occur in the springtime because soil strengths decrease up to 50% from freezing and thawing.
- 13) Problems recur annually because density and water content change during wet weather and after freeze-thaw cycles.

- 14) When more or less permanent "healing" takes place, it is the result of high density and low water content caused from traffic compacting the soil during time conducive to drying of the subgrade. Under well drained conditions, this condition is sometimes retained especially in dry years.
- 15) Prolonged traffic increases density provided excess stresses do not cause softening. This can result in a net improvement over time. Once softening has occurred however, this effect is lost and is difficult to recover.
- 16) Distress occurs randomly because moisture, density and soil type are never completely uniform. Distress is more severe in the outer wheel path because moisture is always higher near the shoulder.
- 17) Different soils respond differently. This is largely controlled by clay content. Increasing clay content reduces strength significantly.
- 18) Problems are severe in low, poorly drained areas because capillary rise causes high moisture content in the subgrade almost to saturation.
- 19) Failures occur on newly constructed subgrades during gravelling and paving because tire pressures in

truck tires hauling gravel are much higher than in tires on large earthmoving machinery. Furthermore compaction specifications requiring 95% standard density at optimum water content produce soil conditions capable of supporting tires with pressure of only about 345 kN/m^2 .

3.2.5 Oil Treatment and Heavy Duty Pavements

Most of the above discussion can be applied directly to thin asphalt or "oiled" surface roadways as well. The thin asphalt surface does not significantly reduce the stresses applied to the soil because these surfaces are soft (i.e. lack rigidity) and are too thin (less than 30 cms) to provide any significant structural support. In fact, the oiled surface has a negative affect on roadway strength because it prevents evaporation at the surface. This results in an increase in moisture in the soil thereby reducing the strength. Therefore, for a given location, a gravel surface would be expected to have at least as much, if not more, capability to support loads than a thin pavement or oiled surface roadway. Thin asphalt or "oiled" surfaces do, on the other hand, have an advantage over gravelled surfaces during or immediately following rain.

While the mechanisms of distress or failure are similar for gravel surfaces, thin pavements and oil surfaces, it is much

more expensive to repair the thin pavement or oiled surface. This is because the failure is in the subgrade and therefore requires that the subgrade be excavated, dried and recompacted for repairs to be effective. Repairs of this type not only require expensive rework of the subgrade, but also require the replacement of the paved or oiled surface. Similar problems with a gravel road, on the other hand, require only blading and perhaps the addition of some gravel.

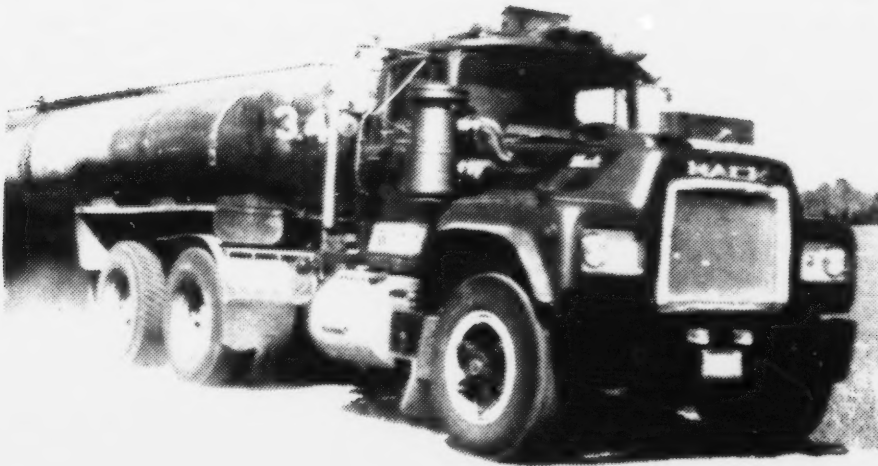
Failure modes in heavy duty pavements are much more complex than in thin pavement, oiled or gravel surfaces. It is beyond the scope of this discussion to draw analogies or make comparisons for this type of surface. It is however worth noting that subgrade failures can occur under heavy duty pavements if the stresses at subgrade level exceed the strength of the soil. It should be sufficient to say, therefore, that the pavement structure should be thick enough to preclude this possibility because as noted with thin pavements and oiled surfaces, subgrade repairs under paved surfaces are very expensive.

It is further worth noting in this context that it is dangerous to extrapolate empirical design procedures such as California Bearing Rates (CBR) etc. to threshold (i.e. failure) conditions, because there is no way of quantifying the threshold values. There is no theoretical basis for any CBR or related design method, therefore any deviation from empirical limits established from experimental data is very

risky and is almost certain to result in unsatisfactory performance.

Figure 3.11 contains a number of photographs which illustrate the above noted discussion.

FIGURE 3.11



TYPICAL TRUCK LOADINGS IN
STUDY AREA



TYPICAL GRAVEL ROADWAY IN
STUDY AREA



TYPICAL DISPLACEMENT FAILURE ON OILED SURFACE



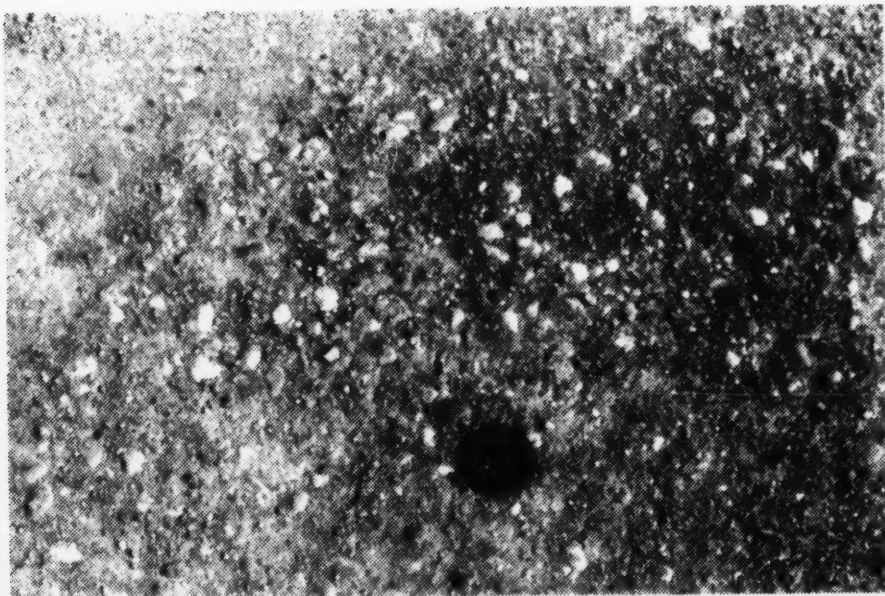
FAILURE OF SURFACE CONSTRUCTED OF WASTE OIL & SAND



REWORKING OILED SURFACE



OILED SURFACE ROADWAY



GRAVEL PACKED IN ROADWAY
SURFACE



TYPICAL NEW GRADE



DEMONSTRATING SOFT SPOT



3.3 Costs of Maintaining Roads

The traffic related costs of maintaining gravel roads is primarily associated with blading, regravelling, reconstruction and treating for dust control.

3.3.1 Blading Costs

The annual costs associated with blading a roadway is largely determined by the frequency of required blading. Frequency in turn is determined by the level of service desired (i.e. surface smoothness), the type and amount of traffic and the moisture conditions.

Typical blading frequency data for the gravel roads within the study area was obtained from the RM of Wilton No. 472. This data is illustrated in Figure 3.12 for the period April through September 11th, 1985. (It was anticipated that the major roads would be bladed once or twice more before freeze-up.)

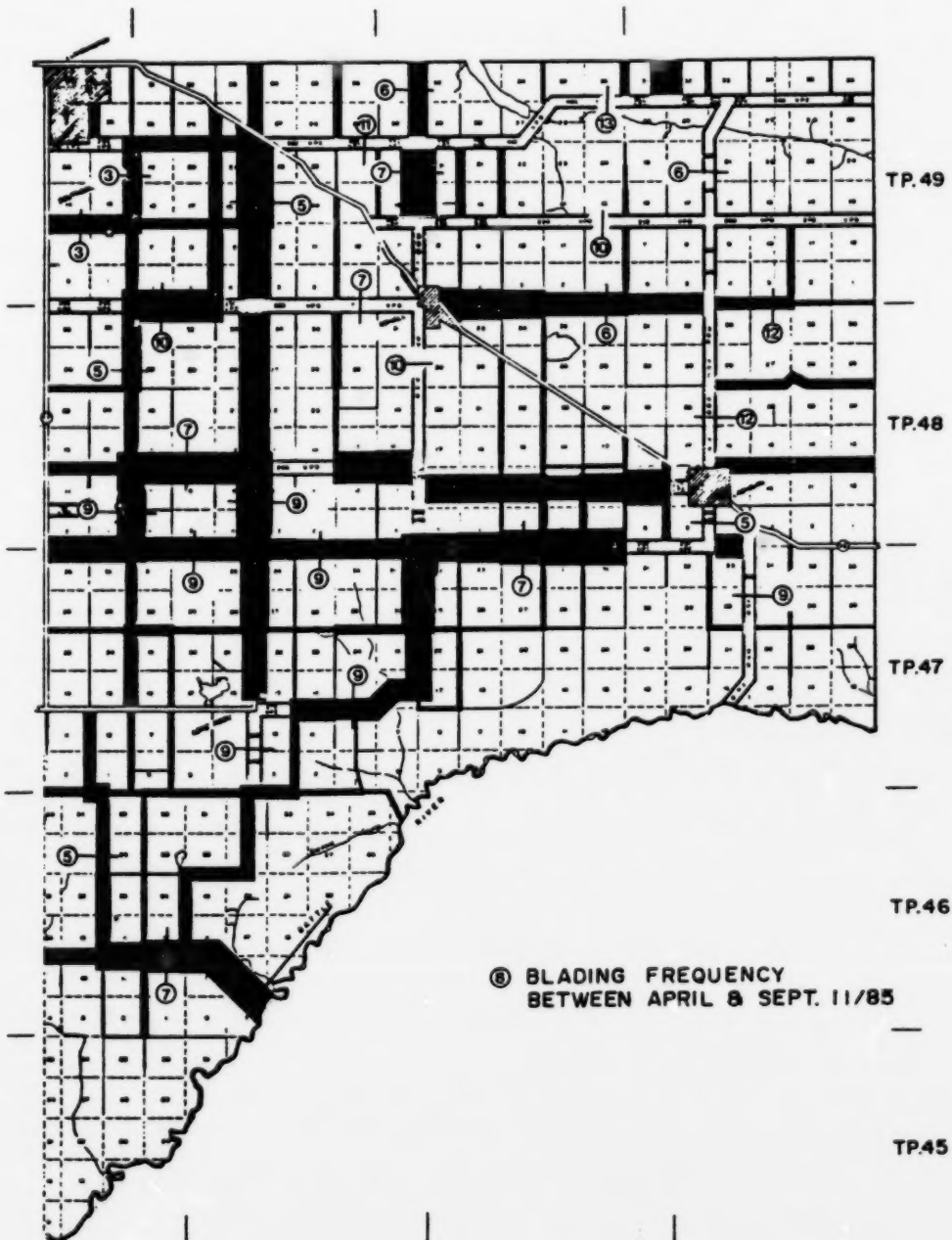
The blading frequency data noted above is plotted vs traffic volumes in Figure 3.13. While the data is highly scattered (therefore suggesting that traffic volume alone does not explain the requirement to blade), there does appear to be a need to blade more frequently as traffic volumes increase. (The slope of the line beyond an average daily traffic (ADT) of 200 v.p.d. is about \$50/year/km per 100 v.p.d.)

FIGURE 3.12

BLADING FREQUENCY AND
TRAFFIC FLOW MAP

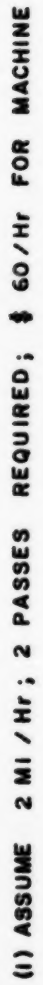
R.M. OF WILTON NO. 472

W OF 3RD



⑧ BLADING FREQUENCY
BETWEEN APRIL & SEPT. 11/85

BLADING FREQUENCY VS TRAFFIC VOLUME RM NO. 472
1985



Also as illustrated in Figure 3.13, there is some considerable uncertainty respecting how blading frequency and traffic are related at low traffic volumes. The data in Figure 3.13 suggests that blading frequency may be nearly independent of traffic up to say 200 v.p.d., with increasing blading frequency required beyond 200 v.p.d. This would be consistent with the requirement to blade all roads after each heavy rain independent of traffic and those roads subjected to heavy traffic at more frequent intervals. This in fact is probably a reasonable representation of what in fact takes place. This then suggests that a basic level of expenditure is required to provide basic service with expenditures then increasing with increasing demand.

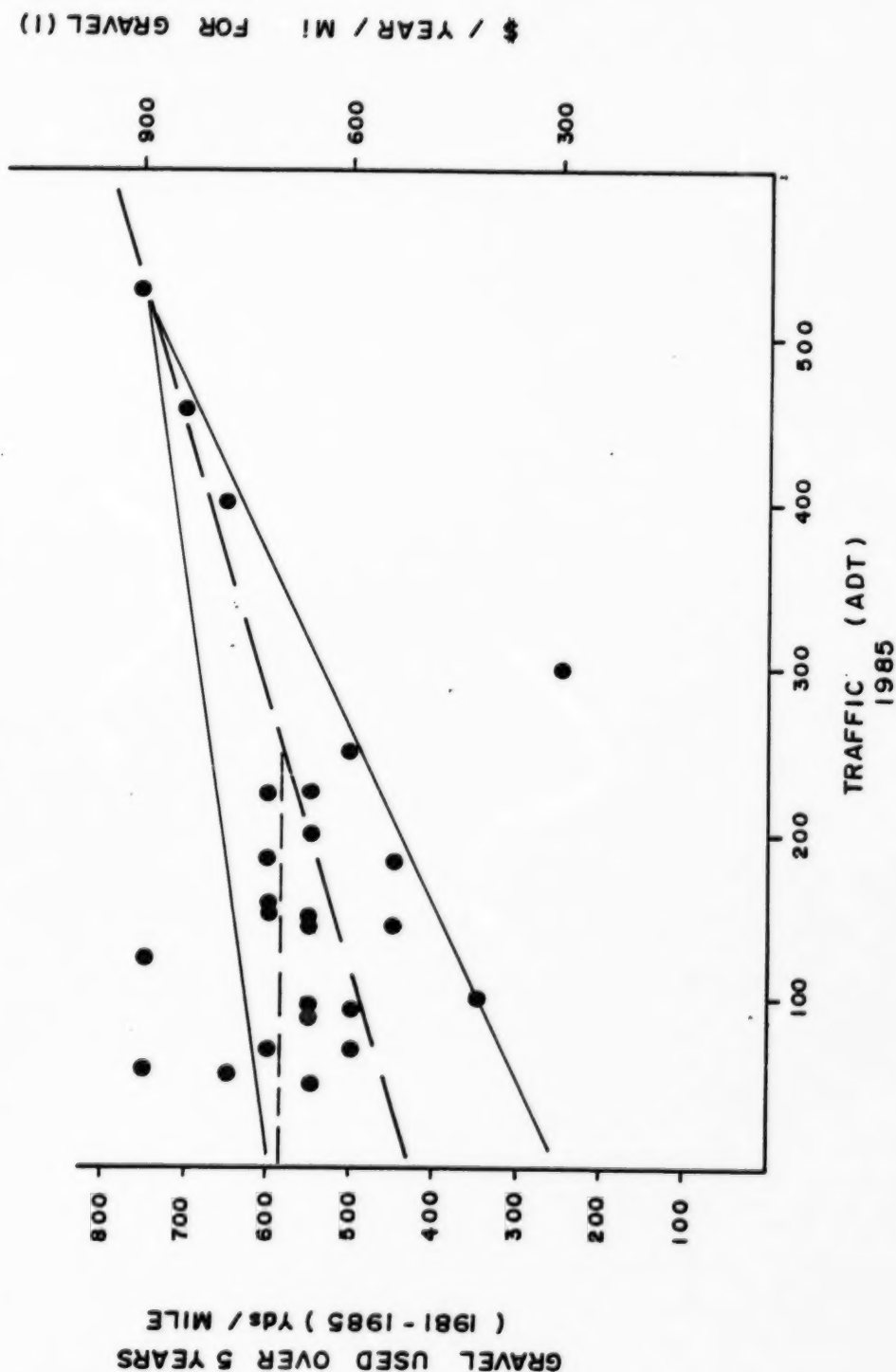
For costing purposes, it is informative to translate blading frequency into \$/km/year for blading as has been done in the right hand axis. As noted, estimated costs for blading per year run in the order of \$200-500/km/year.

3.3.2 Gravelling Costs

Data on regravelling requirements for the RM of Wilton No. 472 and the RM of Eldon No. 471 were obtained. The data for RM No. 472 is plotted in terms of the 5 year gravel requirements vs traffic volume for the 1981-85 period in Figure 3.14. Like blading frequency vs traffic volume, this data exhibits high variability. Again to facilitate costing and further analysis, a costing axis is included in Figure

FIGURE 3.14

5 YEAR GRAVEL REQUIRED VS TRAFFIC VOLUME RM NO 472
1981 - 1985



3.14 and a "best fit" line is drawn. It is noted that regravelling costs are in the range of \$400-900/km/year. This is based on an assumed cost of gravel of \$7.20/m³ (\$6/yd³). Costs for gravel, as illustrated in Table 3.1, vary considerably between RM's and must therefore be given consideration in any costing exercise. The \$7.20/m³ (\$6/yd³) appears to be a reasonable average to use herein for the study area.

3.3.3 Total Costs

In order to develop estimates for the total cost associated with blading and regravelling as a function of traffic, the "best fit" lines in each of Figures 3.13 and 3.14 were replotted in Figure 3.15 and summed as illustrated. This total cost curve was then compared with estimates of blading and regravelling costs as a function of traffic as developed by Rural Development. As noted from Figure 3.15, the estimated total costs for blading and gravelling derived herein compare favorably with those developed by Rural Development.

By making some assumptions as noted respecting composition of total traffic, it is possible to compare the estimates of blading and regravelling costs developed here with similar estimates previously developed by the Department of Highways and Transportation. This comparison is illustrated in Figure

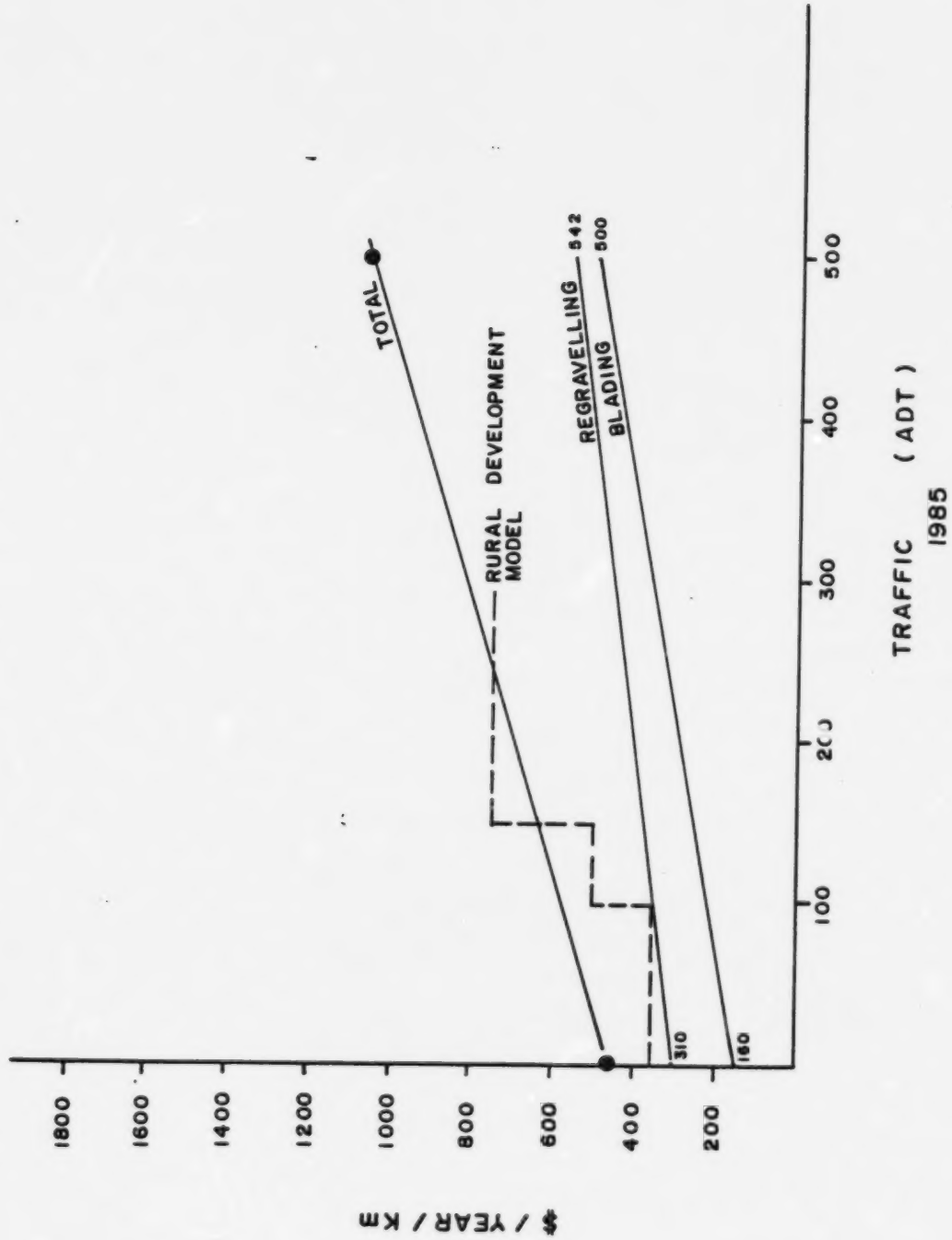
TABLE 3.1
AVERAGE COST OF GRAVEL
\$/Yd³

<u>RM</u>	<u>Grant Year</u>					
	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
168	3.60	4.15	4.70	4.70	4.70	4.55
352	5.00	5.00	4.80	4.85	4.90	5.00
471	2.80	2.85	2.85	2.85	2.85	3.15
472	4.20	4.20	4.10	4.50	5.75	6.15
501	4.00	3.50	3.50	3.50	3.40	3.50
502	3.35	3.70	4.80	4.80	4.80	4.80

SOURCE: Rural Development, as used in Revenue Sharing Calculations
This is a weighted average of gravel costs for each RM

Note: 1985 grant figure is average of 1983, 1982, 1981 gravel
cost, therefore represents 1982 cost

FIGURE 3.15 ANNUAL COST FOR BLADING & GRAVELLING VS TRAFFIC



3.16. It is noted that the estimate developed herein (and therefore the estimates developed by Rural Development) compare favorably with the "Wilkie Model" developed by the Department of Highways and Transportation. This result points out the inappropriateness of utilizing the Sheard Model for our purposes herein.

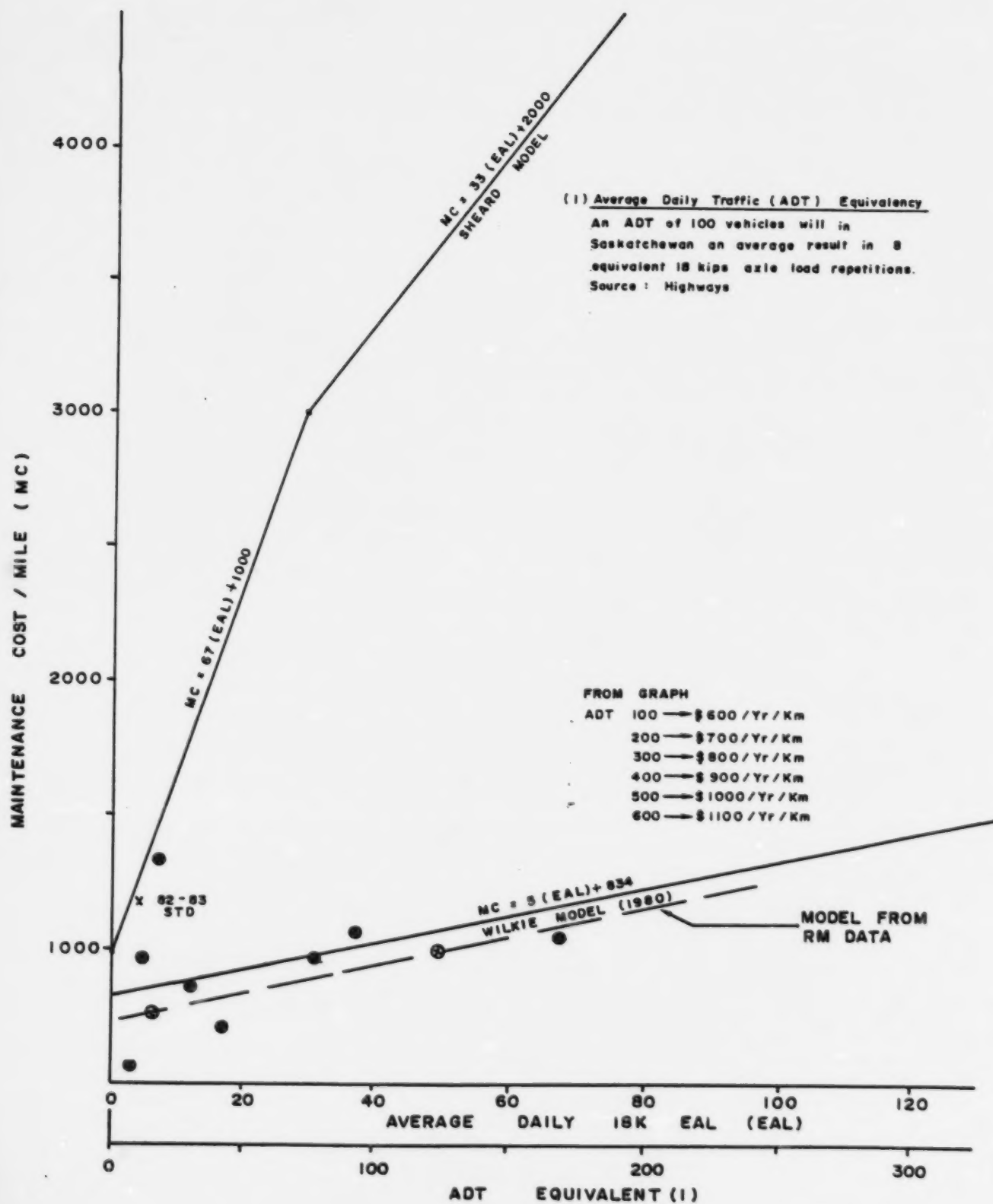
3.3.4 Summary of Costs

The available empirical evidence indicates that the actual frequency of blading and regravelling are not well correlated with traffic alone. Given the discussion in the preceeding section respecting the performance of gravel roadways, this is to be expected. It is however beyond the scope of this effort to pursue this matter further. It is sufficient for our purposes to observe that the costs of blading and regravelling in the area under study are in the order of \$800-1200/km/year for the major roads (i.e. 300-500 vehicles per day) within the study area. Costs are somewhat less for roads with lower volumes of traffic (i.e. 100 vehicles per day).

Further, since blading requirements are in part related to the development of ruts and pot holes, and ruts and pot holes are largely caused by high pressure tires supporting large loads, it is reasonable to conclude that trucks with heavily loaded high pressure tires contribute disproportionately toward the requirement for increased blading. In a similar

FIGURE 3.16

COMPARISON OF COSTING MODELS

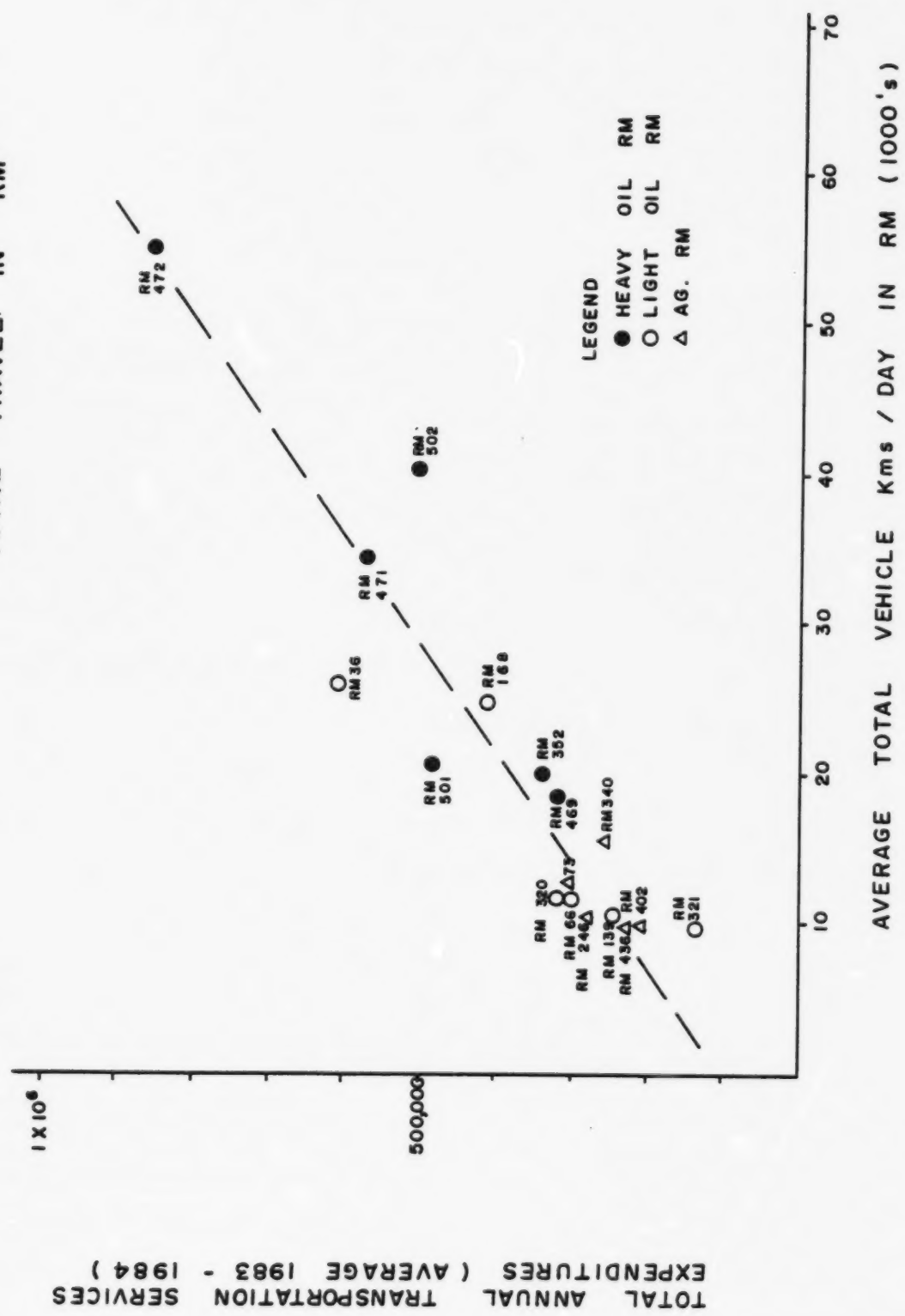


manner, since a large part of the gravel loss is associated with gravel being worked into the subgrade resulting from the development of soft spots in the subgrade, and that these soft spots are largely attributable to high pressure heavily loaded truck tires, it is reasonable to conclude that heavily loaded trucks contribute disproportionately to the requirement to regravell.

As noted above, the micro approach to estimating the costs of providing and maintaining gravel roads provided an estimate for these costs accurate only to an order of magnitude. A macro approach was therefore attempted and is illustrated in Figure 3.17 where total annual transportation expenditures for a number of RM's are plotted versus estimates of the average total vehicle kilometres per day. From Figure 3.17 one notes a general correlation between transportation expenditures and total travel. In particular, it would appear as though the level of expenditures are not dramatically different relative to total travel for those RM's with heavy oil, light/medium oil or only agriculture.

There are however some inconsistencies that are beyond the scope of this effort to explain in detail, however they should be noted. Firstly, RM's No. 501 and 502 both with heavy oil developments, each spend on average about \$500,000 per year on transportation (i.e. roads) however there is twice the total travel in RM No. 502 relative to RM No. 501.

FIGURE 3.17 TRANSPORTATION SERVICES EXPENDITURES
Vs
TOTAL TRAVEL IN RM

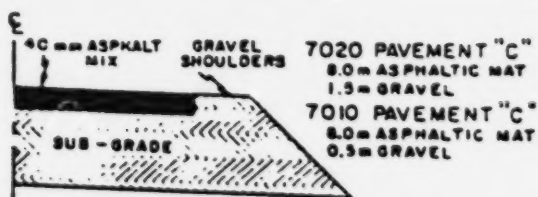
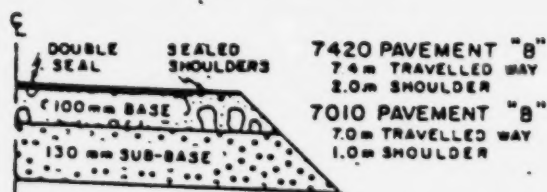
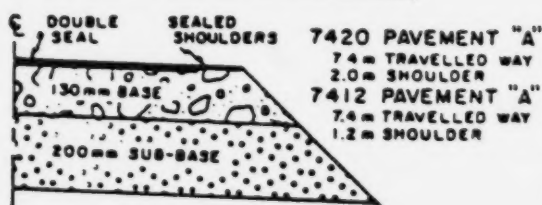
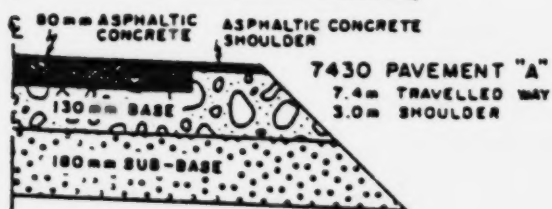
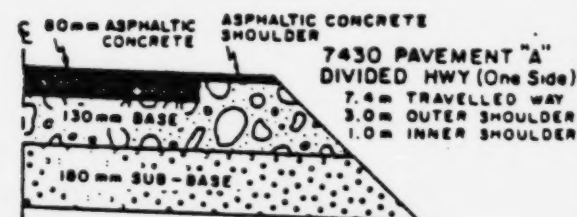
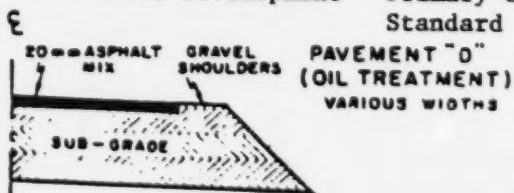


In a similar manner, RM No. 501 and RM No. 352 both have heavy oil developments and about 20,000 vehicle kms/day of travel within their boundaries, however RM No. 501 spends about \$500,000 per year while RM No. 352 spends \$350,000 per year.

These inconsistencies might be in part explained by the fact that RM No. 501 serves a larger area than RM No. 502, and also that RM No. 501 is somewhat rougher terrain. Also, it may illustrate that there is a certain level of maintenance required in any given RM to provide a "basic level" of maintenance to the bulk of the roads. The level of service actually provided is dependent upon the availability of funds and the assignment of priorities within the RM. In all likelihood, the higher the revenues in an RM from whatever sources, the higher the level of service provided.

For comparative purposes the costs of providing and maintaining "paved" roadways experienced by the Departments of Highways and Transportation and Rural Development are summarized in Table 3.2. Of particular interest is the fact that thin pavements (i.e. 40 mm asphalt over subgrade) cost the Department of Highways on average \$60-80,000 per km for grading, \$38,000 per km for the surface and \$2,000-3,500 per km/year for surface maintenance. It cost Rural Development on average for a primary grid type of road \$21,000 per km for grading and \$29,400 per km for surfacing, and \$1893 per year per km for surface maintenance.

TABLE 3.2

TYPICAL HIGHWAY
CROSS - SECTIONS
AND AVERAGE COSTSRural Development - Primary Grid
Standard

AVERAGE COST PER KILOMETRE (1985 \$)			
CONSTRUCTION ¹		TOTAL	SURFACE ⁴ MAINT'CE (ANNUAL)
GRADE ²	SURFACE ³		
110,000	160,000	270,000	830
(For each of the two roadways.)			
155,000	195,000	350,000	1,020
113,000	97,000	210,000	1,140
Constructed on existing 7420 Pvt B	53,000	53,000	
105,000	75,000	180,000	1,630
Constructed on existing 11 m subgrade	62,000	62,000	
79,000	38,000	117,000	2,030
66,000	38,000	104,000	
21,000	29,400	50,400	\$1893 (1984)
(No longer proposed for construction except in special circumstances.)			2200 (1985) Est
			3,450 ⁵

1. Excludes associated works such as bridges, property, design engineering.
2. Grading costs are for level to gently rolling terrain, and include sealing of subgrades.
3. Surfacing costs include crushing of aggregate.
4. Maintenance of road surface, excluding winter maintenance.
5. Includes \$750 for pro-rational seal coating (not included for others).

SOURCE: DEPARTMENT OF HIGHWAYS AND TRANSPORTATION: RURAL DEVELOPMENT AS NOTED.

It is very important to note that these are provincial averages for these types of roadways and there is reason to believe that the average road of this type is subjected to substantially less truck traffic than is experienced on some of the roadways in the study area. (The average road of this type in the province may experience 10-30 equivalent 18 Kip axle load (ESAL'S) repetition, whereas many of the roads in the study area would be subjected to 50-100 ESAL's per day.) In short, the surface maintenance costs for thin pavements and oil treatments if such were used in the study area could be expected to be significantly greater than the provincial average experienced by Highways or Rural Development (i.e. these costs could easily be 2 or 3 times as great - \$4,000-10,000/km/year). This point is substantiated by the experience of the RM of Eldon No. 471, where the maintenance cost for 4 km of oil treatment was \$41,548.10 in 1985 (i.e. \$10,000/km). This involved reworking an oil treatment surface which was not performing adequately (i.e. broken up and rough). It is possible that this type of repair will be required on an annual basis if large volumes of large trucks are permitted to use the road.

3.3.5 Alberta Policy

The heavy oil development in Alberta has resulted in many of the same types of problems related to the provision and maintenance of roads in Alberta as observed within the Saskatchewan heavy oil area. Alberta Transportation, in

recognition of the problem, have funded local road improvements within heavy oil development areas through special road grants and Resource Road Improvement Grants. This assistance has been provided on a case by case basis in response to a demonstrated need.

In the past five years, Alberta Transportation has provided \$1.2 million under the above noted programs to upgrade 30 miles of local roads in the heavy oil area near Elk Point. These roads have all been upgraded to an 8 metre gravel surface standard.

Improvements and upgrading of roadways within Alberta Transportation's jurisdiction have been done on an as required basis within the general policy framework of the Department.

3.3.6 Other Considerations

At least two other considerations are of importance to the issue of the costs of providing and maintaining roads within the study area. These relate to the need for reconstruction of roads and the need to control dust.

Experience indicates that roads subjected to the amount and type of traffic observed within the RM's in the study area require reconstruction more frequently than had been anticipated. This reconstruction is in part associated with

a need to re-establish roadway cross-sections and profiles which have deteriorated over time, as well as a need to increase the standard of roadway because of the increased amount of traffic including large numbers of heavy trucks.

The loss of cross-section and profile of roadways which have been subjected to heavy truck traffic is associated with the failures and displacements of subgrade material as discussed in the section on performance of subgrades. There is really no solution to this short of reconstruction. Turning the shoulders up onto the roadway with the blade during routine maintenance will help, however it is only a partial solution. Roadways which were reconstructed in the 1960's and expected to last 25 years are now requiring reconstruction (i.e. in 20 years). The costs of reconstructing these roads are highly variable depending on the location, amount of grading required, availability of material etc., however typical costs range in the \$15,000-55,000 per km area.

Given the amount of traffic as well as the large number of trucks on roads within the study area, dust near farmsteads as well as generally throughout the area is a nuisance and a safety hazard. Some attempts have been made to control dust near farmsteads by using waste oil and sand from the cleaning plants. This is only marginally successful because this material will not stand up to traffic and then requires reworking. This is relatively time consuming and therefore expensive. The use of conventional road oils to control dust

has also been utilized, however these surfaces also break up as would be expected under heavy (truck) traffic with the resulting need to re-do the surface relatively frequently, (i.e. every year).

A more acceptable solution from the road maintenance point of view is to use a dust inhibitor like calcium chloride on the gravel surface. This approach will effectively control the dust and will not adversely affect the ability to blade the surface, however it is relatively expensive (i.e. \$1400-1800/km for the first application, and \$1100-1300/km for repeat applications). Roads treated with calcium chloride would require re-application at least once and maybe twice each year in high volume locations.

It was noted above that some roads within the study area require reconstruction in part because their standard must be upgraded to adequately serve the demand. Most of the construction undertaken in the 1960's and earlier was done to a standard adequate to serve relatively low volumes of traffic (i.e. less than 150 vehicles per day) consisting of relatively low volumes of large trucks. The single most important parameter relative to upgrading is surface width. The surface width typically used in the 1960's was in the order of 7 m. This combined with other standards of the day was adequate to meet the demands. With the dramatic increase in traffic associated with the increased level of activity within the study area, plus the increase in the number of

large trucks, roads of this standard are in many cases inadequate, particularly in terms of surface width.

The wider surface not only provides more lateral clearance for passing vehicles, but it also provides the subgrade with more structural capability to support the loads. In particular, the wider grade somewhat reduces the problem associated with structural failure of the shoulders of the roadway under heavy loads.

The problem is not one that roadway standards are inadequate, but rather one of providing the recommended standard given the volume and type of traffic. The roadway standards used by Rural Development and Highways have over time proved to be appropriate. The problem is if the road is to experience a demand of 500 vehicles per day, it should be constructed to a standard to serve this volume, not to a standard to serve 150 vehicles per day. In short, the problem is not one of the adequacy of roadway standards but rather one of not being able to anticipate the dramatic growth in traffic and provide the required standards of roadway to serve these needs in a timely manner.

3.4 Summary

The primary variables related to the performance of gravel roads, thin pavements and oil treatments are loading (tire pressure and tire load), soil type (clay content) and soil

condition (moisture content and density). These parameters and their values typically found within the study area explain the manner in which various types of road surfaces are observed to perform.

When gravel surfaced roads are subjected to the volume and type of traffic experienced within the study area, these roadways can be expected to develop pot holes, ruts, soft spots, etc. and require frequent blading, regravelling and reconstruction. The blading and regravelling can be expected to cost \$800-1200 per km per year to provide a minimally acceptable level of service. There is also a need, in some cases, to reconstruct existing roadways so as to re-establish the roadway cross-section and profile, and/or to make the roadway standard consistent with the amount and type of traffic served. This reconstruction can be expected to cost \$15,000-55,000 per km.

Thin pavements and oil treated surfaces would not be expected to stand up to the volumes, but more particularly the type of traffic (i.e. large heavy trucks) found within the study area. If these types of roadways were constructed and large numbers of large trucks were permitted to use them, they are unlikely to perform adequately (i.e. they will break up, become full of pot holes and be very rough). They could be expected to require reworking as frequently as every year at a cost of \$5,000-15,000 per km or more. Heavy duty pavement structures designed to accommodate the truck traffic observed

on many roads in the study area would be expected to cost \$200,000-300,000 per km to construct and \$800-1200 per km/year to maintain.

In short, while the gravel roads within the study area may seem to cost a lot to maintain, it is possible to provide a roadway surface for \$1,000-2,000 per km per year. In relative terms, this is cost-effective. Thin pavements and oil treatments may solve the dust problems, however they will not provide acceptable service for extended periods of time if subjected to heavy truck traffic. Further, they could cost 5-10 times as much to maintain. Heavy duty pavements, on the other hand, could be expected to provide acceptable services, however they cost \$200,000-300,000 per km and therefore their cost-effectiveness comes into question.

Chapter Four: Expenditures and Revenue

4.1 Introduction

The Provincial and Municipal (RM) governments receive revenue from oil related activities. They also incur costs associated with providing infrastructure and services, the demands for which are in part generated by oil related activities. The essence of the issue at hand herein is whether the oil industry pays it's way relative to the demands it places upon the roadway infrastructure provided by the Provincial and Municipal governments. This question is addressed in part in this chapter by presenting a summary of transportation related expenditures incurred by the RM's in the study area and comparing these with revenues received from oil related assessments, conditional and unconditional grants and other direct revenues. This is complemented by a summary of revenues received by the Provincial government by way of taxes and royalties.

4.2 RM Transportation Expenditures

Table 4.1 summarizes and Figure 4.1 illustrates the expenditures made by various RM's for transportation services in 1983 and 1984. (See Appendix A for summaries of expenditures for 1980-1984.)

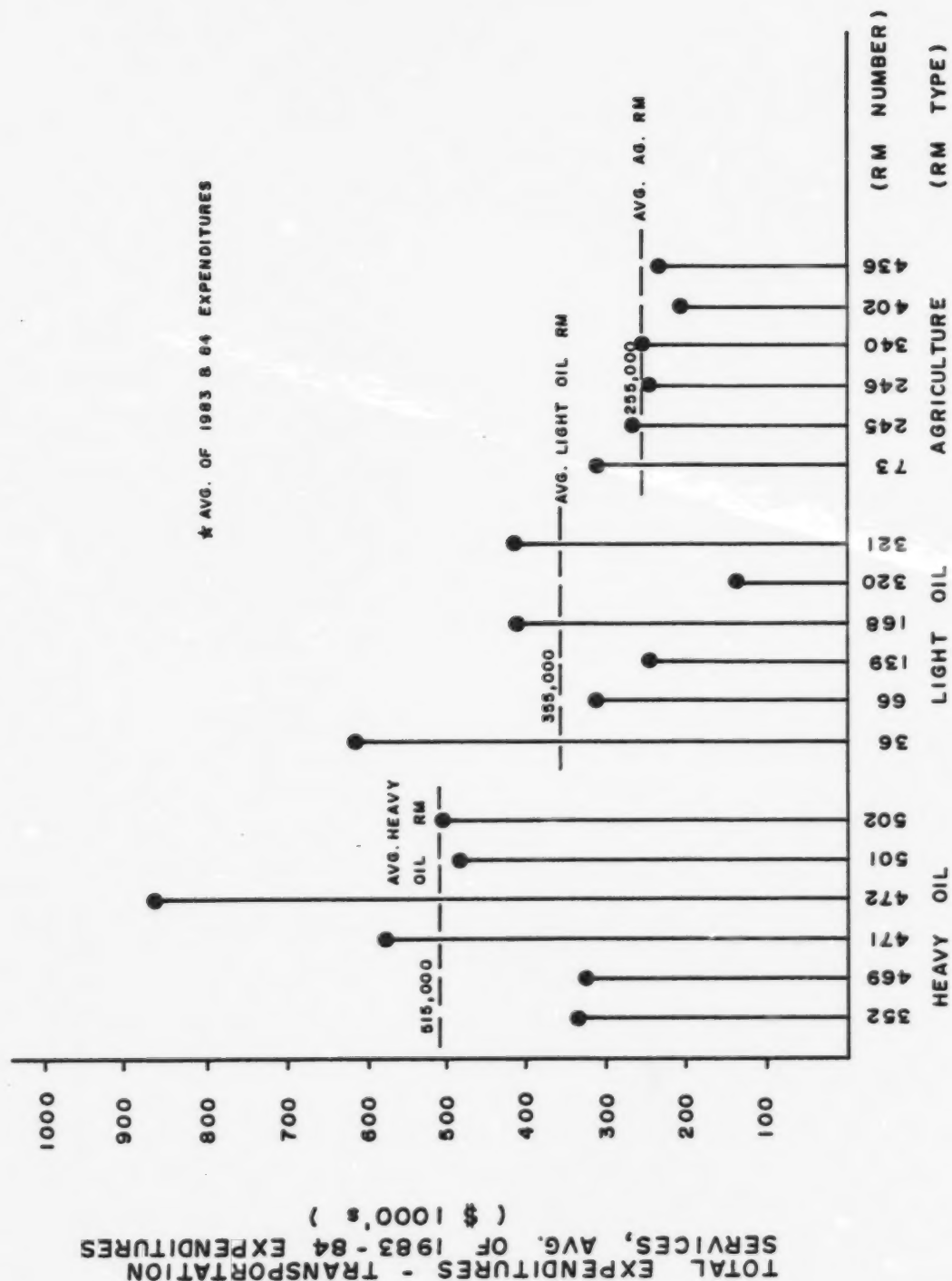
From Table 4.1 it can be seen that expenditures on

TABLE 4.1
TOTAL TRANSPORTATION EXPENDITURES

<u>RM NO.</u>	<u>1983</u>	<u>1984</u>	<u>AVERAGE</u>
<u>HEAVY OIL DEVELOPMENTS</u>			
352	344,000	329,000	337,000
469	365,000	288,000	327,000
471	516,000	633,000	575,000
472	778,000	945,000	862,000
501	439,000	530,000	485,000
502	542,000	462,000	<u>502,000</u>
			515,000
<u>LIGHT/MEDIUM OIL DEVELOPMENTS</u>			
36	715,000	505,000	610,000
66	218,000	384,000	301,000
139	285,000	212,000	249,000
168	480,000	363,000	421,000
320	410,000	404,000	407,000
321	118,000	160,000	<u>139,000</u>
			355,000
<u>AGRICULTURE</u>			
73	342,000	270,000	306,000
245	-	-	255,000
246	357,000	185,000	271,000
340	232,000	275,000	254,000
402	191,000	218,000	205,000
436	219,000	253,000	<u>236,000</u>

SOURCE: RM Financial Statements

FIGURE 4.1 RM TRANSPORTATION SERVICES
EXPENDITURES* Vs RM TYPE



transportation services vary substantially from year to year (i.e. RM No. 469: \$365,000 in 1983, \$288,000 in 1984 for a year to year variation of about 20%).

From Figure 4.1 it is noted that transportation expenditures vary dramatically from one RM to another (i.e. \$327,000 in RM No. 469 to \$862,000 for RM No. 472, both with heavy oil). It is also noted that some RM's with light/medium oil development spend more on transportation than some RM's with heavy oil developments (i.e. RM No. 36 at \$610,000 vs RM No. 352 at \$337,000). The same is true for RM's with only agriculture versus RM's with light/medium oil.

The conclusion to be drawn from the above is that it is impossible to make generalizations because of the high variability. However, RM's with intense heavy oil development (i.e. RM's No. 471 and 472) do have among the highest if not the highest transportation related expenditures of any of the RM's studied.

4.3 RM Oil Related Revenues

Table 4.2 summarizes the details of revenue received by the RM's in the heavy oil area from oil services as well as from Provincial revenue sharing grants (conditional and unconditional). Table 4.3 summarizes similar data for 6 RM's with light/medium oil developments. From Table 4.2 it is noted that oil related revenues as a percent of total RM

TABLE 4.2

SUMMARY OF RM REVENUES
RM'S IN HEAVY OIL AREA

R. M. TAXABLE ASSESSMENTS					R. M. REVENUES		PROV REVENUE SHARING GRANTS					
YEAR	OIL AND GAS WELLS ¹	TOTAL	OIL ASSESS. AS % OF TOTAL	MUNICIPAL MILL RATES (MILLS)	OIL TAXES	DRILLING LICENCES & PERMITS	OTHER ²	TOTAL OIL REVENUE	TOTAL MUNICIPAL	OIL REV AS % OF TOTAL	CONDITIONAL	UNCONDITIONAL
R.M. 352												
1980	397,480	2,473,400	16.1	67.2	26,711	19,500	174	46,385	173,138	26.8	40,300	56,137
1981	773,980	2,852,770	27.1	68.2	52,785	23,106	125	76,016	205,399	37.0	124,100	55,482
1982	1,147,640	3,243,250	35.4	78.1	89,631	2,100	-	91,731	265,946	34.5	124,300	51,398
1983	1,224,920	3,318,340	36.9	82.0	100,443	1,200	300	101,943	272,104	37.5	119,700	42,899
1984	1,227,510	3,363,350	36.5	83.3	102,252	11,400	-3	113,652	280,167	40.6	50,000	27,031
R.M. 469												
1980	37,780	1,298,550	29.0	70.5	2,663	15,200	68	17,931	103,884	17.3	54,000	64,753
1981	142,520	1,399,240	10.2	84.0	11,972	4,800	2,092	18,864	132,928	14.2	35,000	64,335
1982	177,160	1,433,110	12.4	101.2	17,929	6,900	744	25,573	265,125	9.6	67,200	77,188
1983	246,950	1,506,270	16.4	118.0	29,140	12,610	127	41,877	201,840	20.7	76,300	75,329
1984	375,400	1,638,410	22.9	114.7	43,058	10,500	16,295*	69,853	187,926	37.2	99,500	82,072
R.M. 471												
1980	3,919,910	6,548,680	59.9	59.3	232,451	52	761	233,264	437,762	53.3	39,000	7,603
1981	4,257,080	6,874,170	61.9	83.5	355,466	34,169	6,638	396,273	687,417	57.6	127,000	8,749
1982	4,896,850	7,496,480	65.3	84.8	415,253	15,317	3,766	434,336	749,648	57.9	85,900	9,426
1983*	4,787,958	7,496,480	63.9	94.0	450,068	22,585	3,722	476,375	735,387	64.8	85,900	10,407
1984**	6,005,579	9,275,989	64.7	75.9	455,823	22,835	1,047	479,705	704,048	68.1	96,600	11,242
R.M. 472												
1980	4,443,270	8,474,110	52.4	90.5	402,116	29,140	2,250	433,506	819,726	52.9	97,600	12,289
1981	4,682,450	8,932,465	54.7	100.0	488,249	15,428	3,101	506,778	948,426	53.4	211,200	12,118
1982	4,993,680	9,123,460	54.7	100.1	499,867	11,565	581	512,013	1,103,729	46.4	159,700	13,469
1983*	5,232,178	9,123,460	57.3	130.8	684,369	4,181	4,413	692,963	1,171,821	59.1	154,000	15,486
1984**	6,285,425	10,962,652	57.3	106.9	604,483	16,607	3,669	704,759	1,193,832	59.6	160,000	17,252

R. M. TAXABLE ASSESSMENTS				R. M. REVENUES			PROV REVENUE SHARING GRANTS					
YEAR	OIL AND GAS WELLS ¹	OIL ASSESS. AS % OF TOTAL		MUNICIPAL MILL RATES (MILLS)	OIL TAXES	DRILLING LICENCES & PERMITS	TOTAL OIL REVENUE		OIL REV AS % OF TOTAL	TOTAL MUNICIPAL	CONDIITIONAL	UNCONDITIONAL
		TOTAL	% OF TOTAL				OTHER ²	REVENUE				
R. M. 501												
1980	462,880	2,870,060	16.1	95.0	43,974	12,305	-	56,279	17.4	323,723	144,400	106,727
1981	1,089,070	3,512,880	31.0	100.0	108,907	11,130	-	120,037	34.2	351,288	182,700	99,187
1982	1,140,710	4,286,100	26.6	100.0	114,071	9,320	9,345	132,736	31.0	428,610	136,100	84,152
1983	1,244,330	4,411,060	28.2	105.0	130,655	19,200	2,743	152,598	28.6	533,465	134,400	75,588
1984	1,489,410	4,667,710	31.9	107.0	159,367	24,930	1,487	185,784	37.2	499,445	133,400	93,735
R. M. 502												
1980	2,633,870	5,088,925	51.8	100.0	263,387	26,800	174	290,361	57.0	509,264	106,000	31,003
1981	2,917,940	5,426,720	53.8	100.0	291,794	11,700	573	304,067	56.0	542,672	148,200	36,954
1982	2,986,490	5,538,930	53.9	115.0	343,446	3,300	1,008	347,754	54.6	636,977	133,300	44,531
1983*	2,910,545	5,539,260	52.5	117.1	340,825	2,400	298	343,523	49.9	688,942	137,300	58,336
1984**	3,362,778	6,503,526	51.7	100.2	336,950	10,500	412	347,862	53.4	651,653	141,300	60,592

* equalization factor .38 (average), equalized assessment figures and mill rates shown

**equalization factor .45 in all cases, equalized assessment figures and mill rates shown

¹ includes oil and gas wells and pipe line properties

² uncatagorized

³ one time payment of \$5,000 from Petro Canada not included

*one time payment of \$50,000 from Cantarra Energy, a verbal maintenance agreement, not included

SOURCE: Rural Municipal Financial Statements

Saskatchewan Rural Development
Planning & Research Branch
June 1985

TABLE 4.3

SUPPLY OF RM REVENUES

RM'S WITH LIGHT/MEDIUM OIL DEVELOPMENTS

YEAR	R.M. TAXABLE ASSESSMENTS				R.M. REVENUES				PROV REVENUE SHARING GRANTS			
	OIL AND GAS WELLS	TOTAL	OIL ASSES. AS % OF TOTAL	MUNICIPAL MILL RATE (MILLS)	OIL TAXES	DRILLING LICENSES & PERMITS	OTHER	TOTAL OIL REVENUE	TOTAL MUNICIPAL	OIL REV AS % OF TOTAL	CONDITIONAL	UNCONDITIONAL
R.M. 36												
1980	3,793,070	6,013,440	63.1	67.0	254,136	5,625	-	259,761	495,776	52.4	25,000	10,443
1981	3,728,070	5,955,620	62.6	76.0	283,333	2,100	-	285,433	594,443	48.0	35,000	9,092
1982	3,733,250	5,960,550	62.6	88.0	233,701	2,795	-	236,496	733,769	32.2	50,000	9,794
1983	3,735,110	5,963,190	62.6	96.0	358,570	6,700	-	365,270	855,271	42.7	202,174	9,993
1984	3,848,810	6,081,300	63.3	101.0	388,730	15,370	-	404,100	951,339	42.5	217,177	10,658
R.M. 66												
1980	832,420	3,610,440	23.1	62.0	51,610	630	-	52,240	306,968	17.0	25,000	19,801
1981	834,400	3,612,130	23.1	67.0	51,733	300	-	52,033	328,089	15.9	62,400	38,914
1982	801,880	3,617,580	22.2	82.0	65,754	3,000	-	68,754	525,017	13.1	75,200	25,045
1983	813,690	3,629,370	22.4	88.0	71,605	6,930	-	78,535	392,817	20.0	25,058	52,983
1984	848,560	3,675,760	23.1	92.0	78,068	18,620	-	96,688	541,649	17.9	116,282	67,914
R.M. 139												
1980	1,921,710	3,512,220	54.7	80.0	153,737	1,600	-	155,337	312,417	49.7	36,000	15,648
1981	1,926,490	3,515,440	54.8	88.0	105,572	905	-	106,477	371,495	28.7	35,000	21,788
1982	1,930,020	3,713,080	52.0	88.0	169,842	640	-	170,482	381,100	44.7	50,000	17,663
1983	1,945,160	3,723,090	52.3	93.0	180,900	1,955	-	182,855	402,513	45.4	49,019	18,444
1984	1,941,490	3,720,820	52.2	93.0	180,559	2,725	-	183,284	384,518	47.7	48,677	10,944

TABLE 4.3 (Continued)

SUMMARY OF R.R. REVENUES

R.R.'S WITH LIGHT/MEDIUM OIL DEVELOPMENTS

YEAR	R.M. TAXABLE ASSESSMENTS				R.M. REVENUES				PROV. REVENUE SHARING GRANTS			
	OIL AND GAS WELLS	TOTAL	OIL ASSESS. AS % OF TOTAL	MUNICIPAL MILL RATE (MILLS)	OIL TAXES	DRILLING LICENSES & PERMITS	OTHER	TOTAL OIL REVENUE	TOTAL MUNICIPAL	OIL REV AS % OF TOTAL	CONDITIONAL	UNCONDITIONAL
R.M. 168												
1980	4,079,810	8,317,570	49.1	47.0	200,319	5,855	-	206,174	652,647	31.6	147,955	11,095
1981	4,200,710	8,460,060	49.7	53.0	208,775	6,360	-	215,135	872,632	24.7	150,261	12,053
1982	4,248,720	8,514,540	49.9	65.0	276,167	945	-	277,112	732,902	37.8	127,730	13,453
1983	4,243,800	8,509,650	49.9	70.0	297,066	6,930	-	303,996	828,588	36.7	140,533	14,194
1984	4,336,260	8,596,560	50.4	73.0	316,547	6,310	-	322,857	822,578	39.2	125,534	14,157
R.M. 320												
1980	2,948,030	5,252,170	56.1	48.0	141,505	11,905	-	153,410	413,438	37.1	25,000	6,976
1981	2,975,050	5,279,990	56.3	50.0	148,753	5,005	-	153,758	441,201	34.8	70,000	8,735
1982	3,078,900	5,381,230	57.2	54.0	166,261	8,705	-	174,966	362,610	48.4	50,000	7,751
1983	3,230,410	5,531,670	58.4	56.0	180,903	40,200	-	221,103	490,677	45.1	95,467	9,266
1984	3,800,710	6,104,020	62.3	60.0	228,043	75,615	-	303,658	621,326	48.9	88,435	9,491
R.M. 321												
1980	693,900	2,294,380	30.2	58.0	40,246	1,200	-	41,446	409,328	10.1	25,000	17,664
1981	698,000	2,294,280	30.4	60.0	41,880	2,100	-	43,980	282,504	15.6	138,100	23,694
1982	705,860	2,282,710	30.9	63.0	44,469	900	-	45,369	272,703	16.6	50,000	21,488
1983	714,460	2,295,070	31.1	66.0	47,154	5,400	-	52,554	260,343	20.2	6,709	25,250
1984	771,610	2,339,090	33.0	76.0	58,642	9,300	-	67,942	394,834	17.2	12,000	24,086

SOURCE: Saskatchewan Rural Development
Planning and Research Branch
October 1985

revenues from assessments vary from a low of about 30% to a high of nearly 70% in RM's with heavy oil development. Oil related assessment revenues account for 15-50% of revenues in RM's with light/medium oil developments.

4.4 Provincial Oil Royalties

Table 4.4 summarizes the Royalties received by the Province from crude oil production in Area 1 for the 1978-1984 period. It is noted that these revenues totalled nearly a \$100 million in 1983-84.

Table 4.5 summarizes the Royalties received by the Province from land sales from Area 1 in the 1979-84 period. While these revenues have been highly variable (i.e. \$6-40 million per year) revenues totalled about \$20 million in 1984.

4.5 Future Oil Related Revenues

Oil related revenues accruing to the RM's come primarily by way of assessment based revenues as well as drilling licenses and permits. Since it is anticipated that heavy oil development will continue at a pace at least comparable to recent years (i.e. 500 wells drilled per year) and that assessed values do not change dramatically from year to year, RM revenues from oil related sources can be expected to continue at about recent levels. (This is obviously not a detailed assessment and therefore some care should be used in

TABLE 4.4

PROVINCIAL ROYALTIES FROM CRUDE OIL PRODUCTION IN AREA 1

1978-1979	\$47,982,106.94
1979-1980	\$59,460,373.00
1980-1981	\$68,610,496.00
1981-1982	\$78,885,974.00
1982-1983	\$78,922,337.77
1983-1984	\$92,182,186.58

Notes on Royalties:

See footnote to Table 4.5

TABLE 4.5

PROVINCIAL LAND SALE REVENUES FROM AREA 1

<u>YEAR</u>	<u>TOTAL</u>
1979	19,787,553
1980	40,827,340
1981	15,893,616
1982	9,186,253
1983	6,804,001
1984	20,130,355

Notes on Revenues:

1. Production and land sale revenues cannot be separated out by specific RM and are done solely on an Area basis. Therefore, the revenues for Area 1 include all of the study area except RM No. 352 (See Mineral Development Map).
2. Crude oil production revenues are done on a fiscal year and land sale revenues on a calendar year.
3. Land sale revenues include revenues received for the sales for both oil and gas bids primarily in the Beacon Hill area.

extrapolating the conclusion, however in general, RM oil related revenues can be expected to continue as per recent years.)

Saskatchewan Energy and Mines expect that Provincial Royalties from oil related activities in Area 1 will continue in the \$80-100 million per year range for the next 5 years.

4.6 Comparison of Revenues and Expenditures

Figure 4.2 presents a comparison of the 1984 oil related revenues received by the 6 RM's in the study area and the average 1983-84 expenditures on transportation services. Figure 4.3 presents a similar comparison for 6 RM's with light/medium oil development.

The issue at hand is whether oil related revenues cover oil related transportation expenditures. Table 4.6 presents a summary of % total traffic which is oil related and oil revenues as a % of total transportation expenditures for the RM's under study.

From Figure 4.2 and Table 4.6, it is noted that in RM's with intense heavy oil development and therefore an established assessment base (i.e. RM's No. 471 and 472), approximately 50% of the total traffic is oil related and oil related revenues are in excess of 80% of the total transportation related expenditures. Put another way, 50% of the traffic,

FIGURE 4.2 OIL REVENUES & OIL RELATED TRANSPORTATION EXPENDITURES (1984 REVENUES 1983-84 AVERAGE EXPENDITURES)

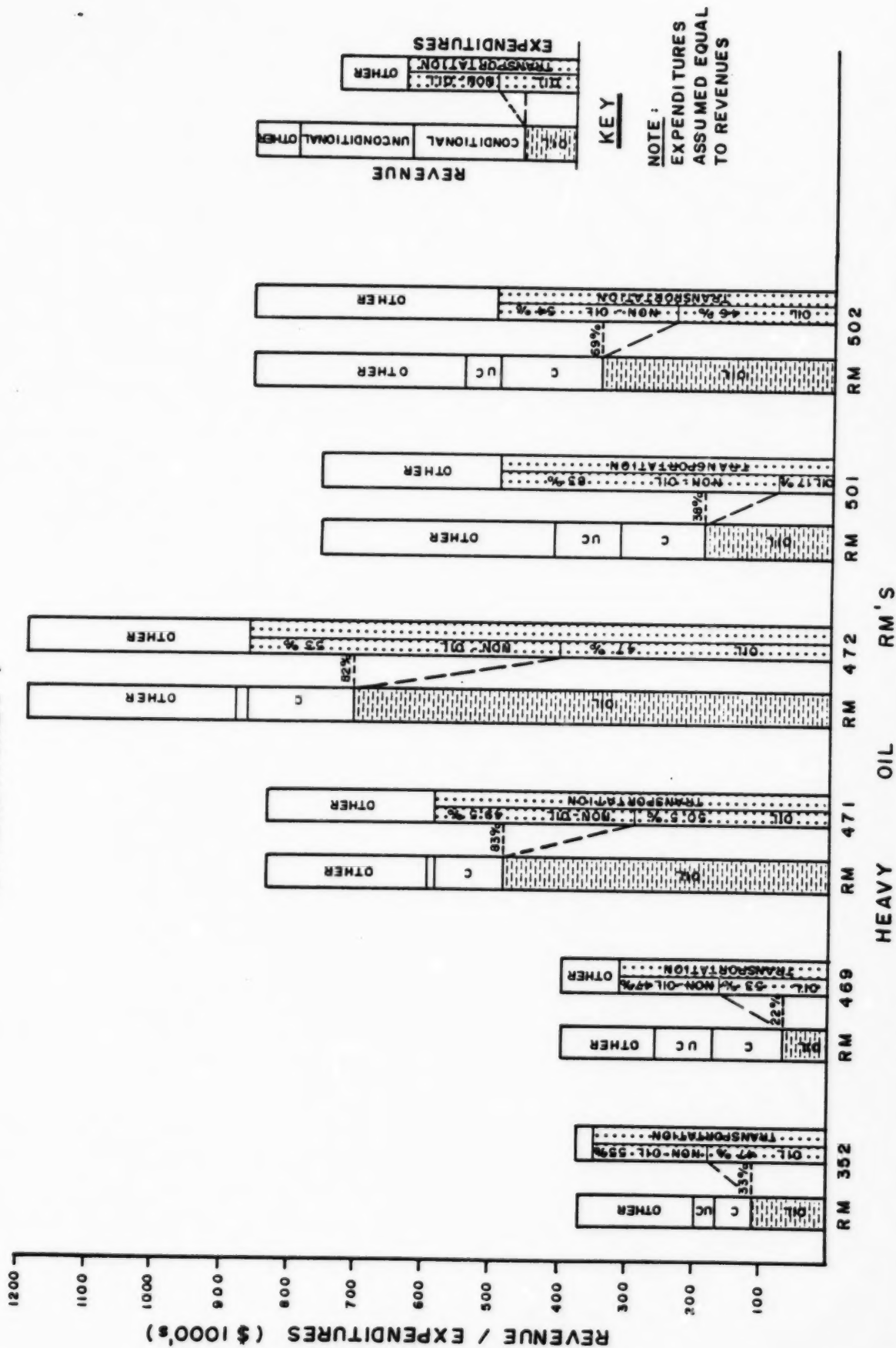


FIGURE 4.3 LIGHT OIL RM REVENUES & EXPENDITURES 1984

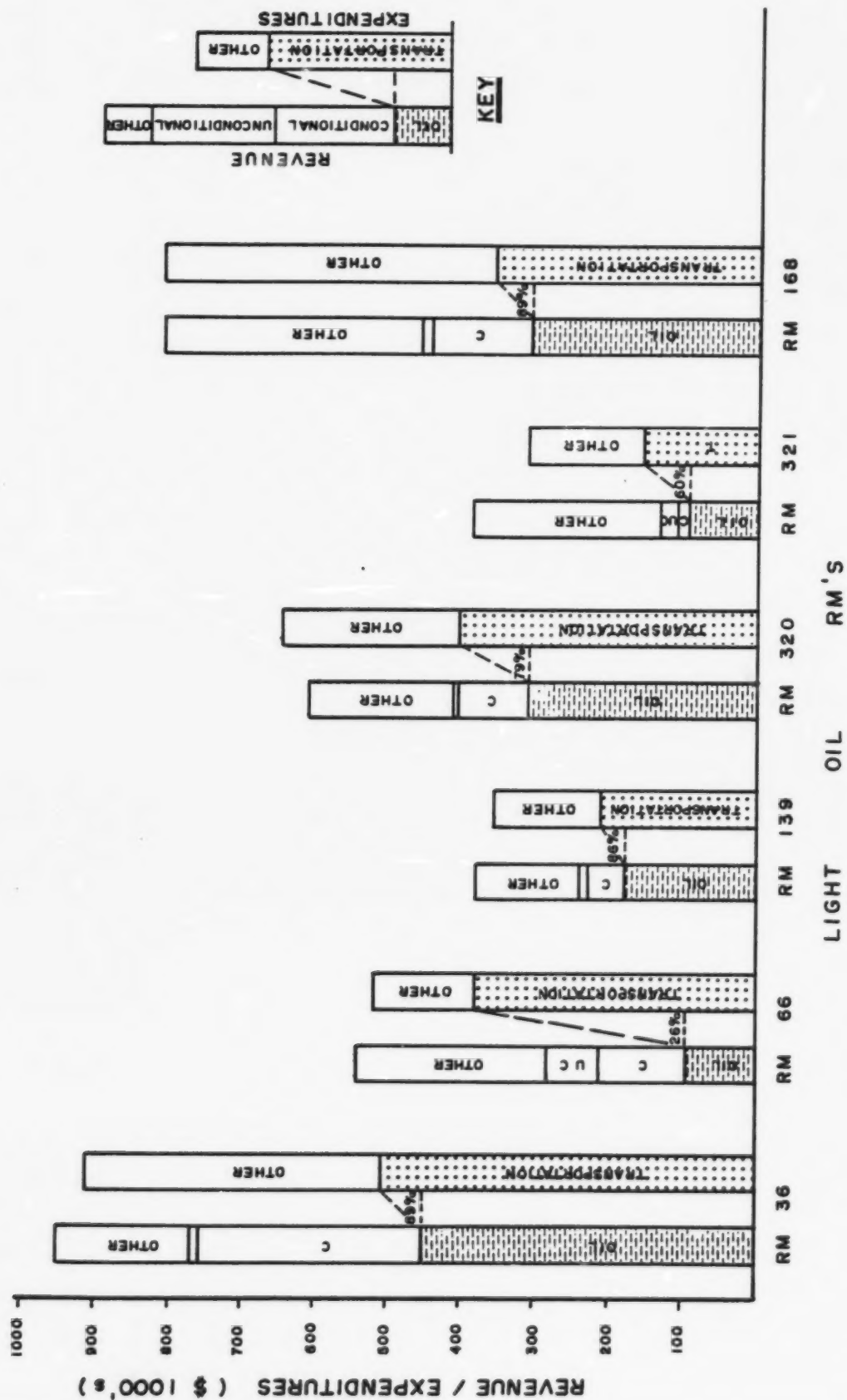


TABLE 4.6

SUMMARY

TRAFFIC - REVENUE - EXPENDITURES - WELLS

	<u>RM</u>	<u>% TRAFFIC OIL RELATED</u>	<u>OIL REVENUE AS % OF TRANS. EXP.</u>	<u>PRODUCING WELLS</u>		
				<u>1979</u>	<u>1984</u>	<u>INCREASE</u>
<u>HEAVY OIL</u>	352	47%	33%	4	194	190
	469	53%	22%	3	98	95
	471	50%	83%	615	1000	385
	472	47%	82%	806	929	123
	501	17%	38%	51	261	210
	502	46%	69%	407	568	161
<u>LIGHT OIL</u>	36		89%			
	66		26%			
	139		86%			
	320		79%			
	321		60%			
	168		89%			

in this case oil related, pays 80% of the costs of providing and maintaining the roads in the RM.

On the other hand, in RM's without established oil related assessments (i.e. RM's No. 352 and 469), traffic surveys indicate that approximately 50% of the total traffic is oil related, yet oil related revenues only amount to 20-30% of the total costs of providing and maintaining the RM roads. In RM's No. 501 and 502, 17% and 46% of the traffic is oil related and oil revenues amount to 38% and 69% of transportation expenditures respectively.

Table 4.6 and Figure 4.3 illustrate a similar situation for RM's with light/medium oil. That is, in areas with established oil activities, oil related revenues amount to 80% or more of total transportation expenditures. Where oil activities are in the development stage, these percentages are substantially lower.

In comparing the percent total traffic with oil revenue as a percent of transportation expenditures, two points of caution must be made. First, some of the traffic data may be biased. The reason for this suspicion is illustrated by the fact that RM's No. 471 and 472 each have intense oil development (i.e. approximately 1000 producing wells) and in these RM's oil related traffic represents approximately 50% of total traffic. On the other hand, RM's No. 352 and 469 have only 190 and 95 producing wells respectively (i.e. 1/5 to 1/10 the

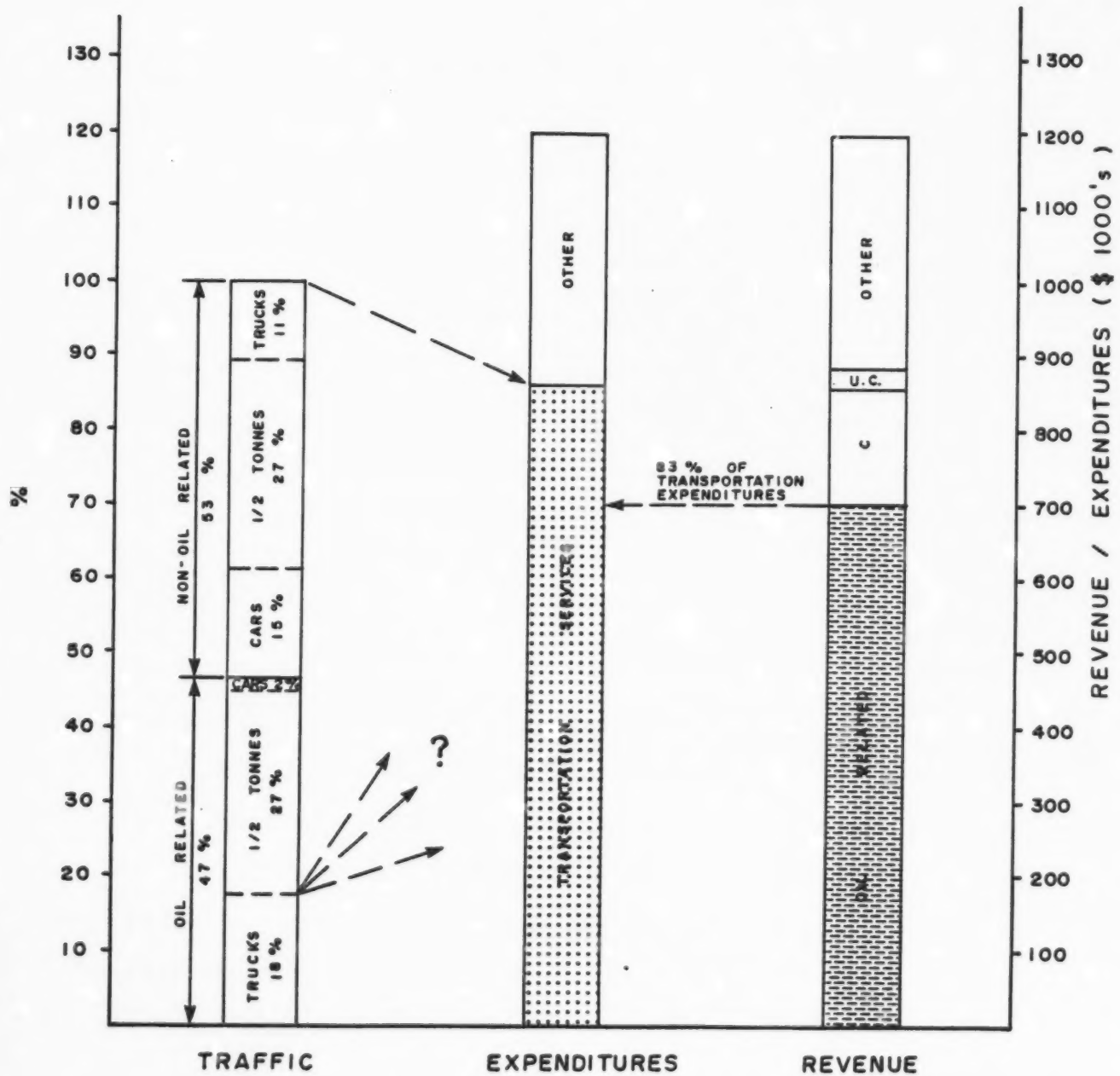
number when compared to RM's No. 471 and 472) yet the traffic surveys indicate that about 50% of the traffic is oil related.

Intuitively one would expect oil related traffic to be somewhat more in line with the number of wells producing. It is not appropriate within the scope of this effort to speculate on the reason for this seeming inconsistency, but sufficient to note that it exists. Perhaps there is a need to verify earlier counts.

The second point relates to the implication used above that each category of traffic should pay its proportionate share of transportation expenditures (i.e. if 50% of all traffic is oil related, then oil revenues should cover 50% of all transportation expenditures). Unfortunately, as is illustrated below, the cost allocation process is not nearly this simple.

It was noted in Chapter 2 that most of the need for blading, regravelling and reconstruction was generated by vehicles operating with tires at high pressure and wheels supporting large loads (i.e. loaded trucks). That is, there is sound technical reason to suggest that trucks should pay a higher relative proportion of road costs than for example, passenger cars. The issue at hand is illustrated in Figure 4.4 wherein traffic, by component, total transportation expenditures and revenue by source are plotted. The issue is the allocation

FIGURE 4.4 TRAFFIC - EXPENDITURES - REVENUES
RM 472 (1984)



of total transportation expenditures to the various components of traffic. In order to do this allocation on a rational basis, data related to truck types and loadings (i.e. tire pressures and wheel loadings) would be required. While it is impossible to be definitive because of limited data, (and knowledge), it is however possible to observe that:

- 1) in those cases where approximately 50% of the total traffic is covering in excess of 80% of the total costs of providing and maintaining the roads, this component of traffic would appear to be paying its' way,
- 2) in those cases where approximately 50% of the total traffic is covering only 20-30% of the total costs of providing and maintaining the roads, it is unlikely that this component of traffic is paying its' way unless it is composed entirely of vehicles with low tire pressures and light wheel loads.

Even the above general conclusions can be questioned.

The difficulty of arriving at clear cut conclusions from the information available may be further illustrated by the following arguments.

It is dangerous to assume that oil related traffic accounts

for a large portion of the transportation expenditures. Most of the travelled roads in an RM (i.e. probably 90-95%), have traffic volumes of 100 v.p.d. or less. At this level, expenditures are not (directly) related to traffic.

Therefore because of the large number of miles of road that an RM must maintain, the ratio of non-oil to oil related expenditures is not likely the same split as non-oil to oil traffic. Consequently, the oil related expenditures may in fact be covered by oil revenues even when these revenues are only 20-30% of total expenditures. The ratio of oil related traffic to oil related expenditures is therefore unclear but is not a simple 1:1 ratio.

On the other hand, oil related activities tend to carry-on rain or shine, therefore the road maintenance required following periods of wet weather may be more attributable to oil than non-oil traffic.

In short, definitive conclusions are impossible and in some cases oil related traffic appears to be paying its' way and in others it appears not to be.

Chapter Five: Summary

1. It would appear as though the oil industry is paying its way respecting road costs in RM's with established oil related assessments. This is true for RM's with heavy oil as well as those with light/medium oil development.
2. There is reason to believe that RM oil related revenues may lag oil related costs for providing roadway infrastructure during the development period. That is, when development first starts, the oil industry creates demands for roadway infrastructure (i.e. exploration and drilling activities), yet the RM's do not collect significant revenues until the wells are in production and become part of the tax base. There may therefore be a need to examine ways in which RM's might meet the financial requirements of their obligations until the assessment base is established and significant revenues begin to accrue.
3. Some RM's may incur the costs of providing and maintaining roadway infrastructure to meet oil related demands yet because the oil development is not within the boundaries of the RM or limited in scope, the RM may never establish an oil related revenue source sufficient to offset oil generated costs. Clearly, there is a need to address the financial implications of

these situations when they arise. Further, because of the dynamic nature of these situations (i.e. they change with time), it would be best to consider them on an individual case by case basis.

4. It is unclear from the data available for this analysis as to whether the level of service provided varies substantially between RM's. There is reason to believe that this may be the case. RM's tend to do "the best they can" with available resources. In such cases, the level of service is the variable, not expenditures. Therefore, care must be taken to ensure that "apples" are always compared with "apples". There is therefore a need to evaluate this issue of level of service in more detail.
5. The traffic demands on many of the roads within the RM's are at volumes that exceed those on some provincial highways. Given the volume and type of traffic, these demands are therefore significant. In this context, there is a need for the RM's to upgrade roads as required however the availability of funds to meet the needs for upgrading appear to be lagging. There may therefore be a need to examine ways in which the RM's can obtain the required resources so that required upgrading can be done in a timely manner. Roadway standards appear acceptable, it is a question of having the required resources to provide the proper standard of roadway

given the demand. In this context, there is a need to do a detailed evaluation of the existing and future demands relative to appropriate standards and existing roadways.

6. With the high volumes of traffic and the large number of trucks, dust presents not only a nuisance but also a potential safety hazard. Dust is a particular problem near farmsteads and at intersections. If level of service standards used in other RM's and on provincial highways were applied to many of the high volume roads within the RM's under study, dust free surfaces would be justified. In the context of the provincial highway system, these surfaces would typically be provided via the construction of a "B" or "C" type pavements (i.e. thin pavement) at a cost of \$100,000-200,000 per km. In the context of other RM's, these dust free surfaces would be provided via an oil treated surfaces at a cost of \$20,000-40,000 per km. The problem is that these types of surfaces would not be expected to stand up to the truck traffic within RM's with heavy oil development, and would therefore fail to provide acceptable service at reasonable cost. The options are to either construct a heavy duty pavement at a cost of \$200,000-350,000 per km, restrict truck traffic, control dust in another manner or accept a lower level of service. Restricting trucks on some roads would not seem to be

practical. Dust could be controlled by the use of dust inhibitors such as calcium chloride at a cost of \$ 1400/km/year. A major portion of the dust problem could be controlled while reducing overall costs by selectively using calcium chloride on high volume roads near farmsteads and high volume intersections.

7. In short, there would appear to be a need to examine ways in which RM's within the heavy oil development area could obtain the financial resources to:

- a) overcome the lag in revenue relative to costs of providing and maintaining roads when development is in its initial stages,
- b) provide, in a timely manner, the necessary funding to upgrade high volume roads to a standard which will provide an acceptable level of service relative to the demand,
- c) offset the costs incurred in providing and maintaining roadway infrastructure within those RM's where oil related activities create traffic yet there is little or no oil related revenue relative to costs, and
- d) provide a dust control program on high volume roads. As a minimum this program should provide

dust control on high volume roads near farmsteads
and at high volume intersections.

The funding would most appropriately be provided under a
program which could address need on an individual case by
case basis.

LIST OF REFERENCES

1. Study Terms of Reference, Impact of Heavy Oil Development on Highways and Municipal Roads, Saskatchewan Energy and Mines, Saskatchewan Highways and Transportation, Saskatchewan Rural Development, May 17th, 1985
2. Proposal, Impact of Heavy Oil Development on Highways and Municipal Roads, Sparks & Associates Ltd., May 1985
3. Travel on Saskatchewan Highways, Saskatchewan Highways and Transportation, 1984
4. Heavy Oil Study, Traffic Research Section, Planning Branch, Saskatchewan Highways and Transportation, August 1980
5. Unpublished Research by Dr. E.K. Sauer and others.

APPENDIX A

TOTAL RM TRANSPORTATION EXPENDITURES
RM'S WITH HEAVY OIL DEVELOPMENTS

TOTAL RM TRANSPORTATION EXPENDITURES

RM'S WITH HEAVY OIL DEVELOPMENTS

<u>YEAR</u>	<u>CONSTRUCTION</u>	<u>MAINTENANCE</u>	<u>TOTAL</u>
<u>R.M. 352</u>			
1980	39,005	83,997	123,002
1981	179,837	123,457	303,294
1982	115,020	177,736	292,756
1983	188,753	154,763	343,516
1984	131,155	198,238	329,393
<u>R.M. 469</u>			
1980	119,473	125,687	245,160
1981	6,440	108,839	115,279
1982	86,444	121,921	208,365
1983	251,161	114,132	365,293
1984	134,380	153,655	288,035
<u>R.M. 471</u>			
1980	149,358	265,758	415,116
1981	206,011	341,049	547,060
1982	265,478	347,908	613,386
1983	193,399	322,773	516,172
1984	231,052	401,680	632,732
<u>R.M. 472</u>			
1980	323,078	397,531	720,609
1981	675,714	507,686	1,183,400
1982	376,579	624,991	1,001,570
1983	93,401	684,294	777,695
1984	247,331	697,476	944,807
<u>R.M. 501</u>			
1980	317,015	240,574	577,589
1981	141,020	240,341	381,361
1982	110,082	354,583	464,665
1983	135,742	303,587	439,329
1984	148,182	381,721	529,903
<u>R.M. 502</u>			
1980	399,200	172,771	571,971
1981	353,227	487,016	840,243
1982	247,337	495,328	742,665
1983	125,122	417,228	542,350
1984	0	461,907	461,907

SOURCE: R.M. Financial Statements

Planning & Research Branch
Saskatchewan Rural Development
July 1985